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THE RING NEBULA IN LYRA.

H. C. WILSON.

The constellation Lyra, which we see to the west of the zenith in the evening during this season of the year, contains three objects of especial interest. First the lustrous Vega, exceeded in brightness only by Sirius among all the stars in the northern heavens; second, the famous double-double star ε; and third the wonderful annular nebula, the brightest of its kind, and the only one accessible to common telescopes. The Ring Nebula is not visible to the unaided eye, but is easily found by pointing a telescope midway between the stars β and γ Lyræ. The nebula lies almost in a direct line between these stars, two-fifths of the way from β to γ. Its place is indicated in the photograph, plate XXIV, Fig. 1, by a minute dot at the point of the arrow between the stars marked β and γ, in the lower left hand portion of the picture. The star Vega is shown at the upper right hand corner of the plate, the white spot with a halo around it, and the bright stars below and to the left of Vega are ζ and δ Lyræ. The star δ is shown by the photograph to be a wide double, surrounded by a cluster of fainter stars. This plate was made from a portion of a photograph taken August 21, 1897, with the 6-inch Brashear doublet at Goodsell Observatory. The exposure given was one hour. In this photograph the Ring Nebula looks like a faint star, requiring a microscope to show its annular form.

When one directs a small telescope toward the space between β and γ, which is wholly vacant to the naked eye, he is struck with the great number of faint stars that strew the field of view. All of these are minute glittering points except one, which looks dull and hazy and has a perceptible size. A closer look reveals its shape as that of an oval ring, and when one uses a powerful telescope the ring becomes quite brilliant and its interior is filled with a dim nebulous haze. This is the Ring Nebula. It was first noticed by Darquier of Toulouse in 1779. Many drawings have been made of this nebula by well known observers and they agree fairly well. The best perhaps were by Lassell in 1860 at his private observatory in England, Trouvelot in 1871 at Har-

vard Observatory, and Holden in 1875 at Washington. These all agree in showing the sides of the oval as brighter than the ends and a slight extension of diffused light at the ends. Lassell's drawing shows a faint star near the center of the ring, while the other drawings show none. In Lord Rosse's telescope the nebula was completely surrounded by wisps and appendages of all sorts, which other observers have been unable to verify. Several observers speak of the nebula as glittering as if it were a "heap of star dust," but its spectrum indicates that it is principally, if not wholly, gaseous. The great Lick refractor does not resolve the nebula into stars but shows many stellar points within the nebulosity. According to Professor Holden (Mon. Not. R.A. S. 1888) no less than eleven stars besides the central star are seen within the nebula, and the details of structure of the nebula are so numerous and complex as to render it a hopeless task to attempt a drawing of them.

Several photographs of this nebula have been obtained during the last ten years, the first, so far as we know, being by Herr von Gothard at Hereny, Hungary, in 1886. Mr. Isaac Roberts secured a fine photograph in 1887, July 31, with his 20-inch reflector and an exposure of 20 minutes. An excellent photograph was published in Knowledge Nov. 1890, which was taken at Algiers by M. Trepied with a 13-inch refractor and an exposure of six hours. Another taken at the Vatican Observatory with a 13-inch refractor and exposure of $1^h\ 50^m$ is published in *Publicazioni della Specola Vaticana* 1891.

The photographs which we present in connection with this paper were taken at Goodsell Observatory by the writer, with the 8-inch Clark refractor, which has a third lens placed in front of the visual objective to correct it for the photographic rays.

The first, Plate XXIV Fig. 2, was taken Aug. 11, 1896 with an exposure of one hour. The second, Plate XXIV Fig. 3, was taken July 27, 1897 with an exposure of 2 hours. The third, Plate XXIV Fig. 4, was taken Aug. 19, 1897, with an exposure of one hour. Each of these has been enlarged seven diameters in the reproduction. In the original negatives the nebula is a very small object, only a little more than a half millimeter in diameter, so that it is almost wonderful that any detail at all is shown in the structure of the nebula. All three agree in showing the central star, situated as near the center of the ellipse as one can judge by eye. In this they agree with all the photographs of which we have heard, excepting some taken at Paris, which, according to Miss Clerke,* do not show any trace of the central star.

* System of the Stars, p 261.

The larger picture, Fig. 1 Plate XXIII, is enlarged 48 diameters from the negative taken July 27, 1897. The great scale of the enlargement brings out the grain of the original negative very obviously. The reader must not mistake this granulation for an indication of resolvability of the nebula into stars. It is simply due to a tendency of the silver grains, as they are formed by the chemical action in the development of the negative, to gather together in little groups. The nebulous appearance of the central star is not necessarily due to a nebulous character. A true stellar point would produce the same kind of an image if the exposure were insufficient. This will be apparent from the size of the image of the star at the east end of the ring, which shows no trace of nebulosity to the eye. The slight elongation of the star image is due to imperfect control of the driving clock.

The photographs all show that the northern side of the ring is slightly brighter than the southern and that the ends are much darker than the sides. In the original negative the space within the oval is filled with faint nebulosity, but much of this has been lost in the reproduction. No definite traces of any other stars than the central one are shown within the nebula. The images of stars as faint as that in the center could not be distinguished from the surrounding nebulosity.

These photographs afford good examples of both the advantages and disadvantages of the photographic process in astronomy. For determining the exact position of the nebula, its general outlines and relative gradations of light the photograph is far superior to the eye. On the other hand the contrasts between light and shade are always increased in the photograph, so that the absolute differences of light are far from correct. Again, the exposure upon such a faint object must necessarily be prolonged and the continual disturbances of our atmosphere displace the image this way and that upon the plate, so that what should be minute points in the picture are enlarged and overlap each other, thus blurring the whole. The same effect is produced to a greater extent by the spreading of the image in the film while being developed, because of the tendency of the silver grains to group around each other. Unless we can employ a high enlarging power directly in the telescope, while the photograph is being taken, we cannot expect to obtain representations of the minute details of this or any nebula. Each enlargement of the image, however, requires greater light gathering power or longer exposure in proportion to the square of the increase of diameter. It is therefore hopeless to expect that we shall ever be able to so

increase the light gathering power of our telescopes, that we may shorten the exposure on such faint objects to the fraction of a second necessary to avoid atmospheric blurring, and at the same time enlarge the image so as to show minute details.

On the other hand these photographs show about all that can be seen by the eye with a moderate sized telescope, and are far more accurate than any hand drawings could be. The writer believes in the photographic method, especially for depicting the forms of large diffuse nebulæ. The coarser features of the Orion and Andromeda nebulæ are shown, in the numerous photographs which are now extant, with an accuracy of agreement which is in marked contrast with the disagreement between hand drawings made even by the same observers at different times.

ADDED NOTE.—The above was written before the engravings were prepared and everything said in description of the photographs refers to the photographic prints. The engravings fall far short of showing all that can be seen in the photographic prints and the latter also show much less than the original negatives. In Fig. 1 Plate XXIV the faint stars are nearly all lost, not one-tenth part of them remaining. In Figs. 2, 3 and 4 of Plate XXIV and Fig. 1 of Plate XXIII the fainter portions of the nebula are fairly well shown, but in the brighter portions the details are lost. We hope at some other time to present better reproductions of the photographs, which are really excellent.

DEDICATION OF YERKES OBSERVATORY.

W. W. PAYNE.

The exercises which were held in connection with the dedication of the Yerkes Observatory of the University of Chicago opened Monday, Oct. 18, and continued until Friday evening, October 22. These exercises consisted of a series of conferences which were generally held three times each day, at which times papers were presented on such topics of scientific interest as seemed best to bring forward for consideration and discussion by the astronomers and physicists present. The first meeting in this series was held Monday afternoon at the Yerkes Observatory the management of the *Astrophysical Journal* was the topic of consideration, the editors of the same, in open session, bringing to the attention of the meeting things of present interest for the advantage of the publication. This matter occupied the greater part of the afternoon session.

PLATE XXIV.

FIG. 1. PHOTOGRAPHIC CHART SHOWING PLACE OF RING NEBULA.

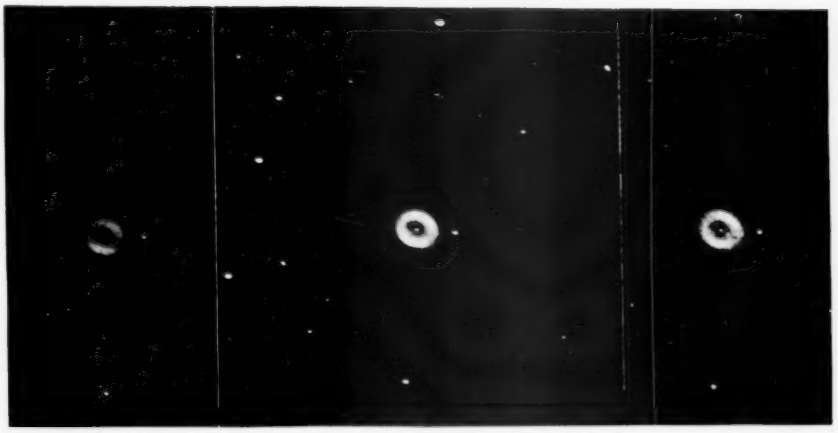


Fig. 2. 1896, Aug. 11. Fig. 3. 1897, July 27. Fig. 4. 1897, Aug. 19

Enlarged 7 diameters.

THE RING NEBULA IN LYRA.

In the evening Professor Burnham used the great 40-inch telescope in exhibiting some double stars chosen to show the power of the mammoth objective. We can not speak of this exhibition, as we were unable to be present. Those who viewed were greatly gratified with what was shown.

On the morning of Oct. 19 the first paper was by Professor Henry Crew of the Northwestern University at Evanston. He described experiments made by himself with a purpose to separate, if possible, the light rays due to electrical action from those due to chemical action at the high temperatures in which both are produced. No definite results were reached in these experiments, but it was suggested, as at least possible, if not probable, that some of the lines of the spectrum of iron were due to electricity, while others may be produced by chemical action. Those who participated in the discussion of the paper expressed great interest in it, and generally agreed that the investigation if pursued is likely to yield important results.

Professor George C. Comstock, Washburn Observatory, Madison, Wis., next described his work on the determinations of stellar parallax and on the investigation of the lunar atmosphere. Concerning the lunar atmosphere, he studied the question by measuring the angular distances of two stars several times while one of them was approaching the dark limb of the Moon. With the apparatus in his possession such measures could be easily and accurately made. He feels warranted in the belief that this method will give good results in the future. The work to date seems to show that the Moon may have an atmosphere which causes a refractive displacement amounting, at the maximum, to one three hundredth part of a second of arc, and that the density of the lunar atmosphere at the surface is about one five thousandth part of the density of our atmosphere at the surface of the Earth. Professor E. C. Pickering of Harvard College Observatory, described a very ingenious method of observation to this end which was employed by his brother, William H. Pickering, during a recent occultation of the Pleiades by the Moon. It consisted in watching the apparent change in the position angle of the line joining two stars one of which is approaching the lunar limb very obliquely, and the conclusion is that there is no unmistakable evidence of the existence of an atmosphere on the Moon. Professor Hugh L. Callendar, of McGill University, Montreal, Ca., called attention to the point made by good scientific authority, two or three years ago, that the kinetic energy of the lighter gases is so great that hydrogen could not be retained at the

surface of the Moon, nor in a free state high up in our own atmosphere. This fact was mentioned in connection with the possible existence of helium in the Earth's atmosphere.

In the afternoon of Tuesday, Professor George E. Hale, Director, delivered his address on the Yerkes Observatory, in which he directed the attention of visiting astronomers to the recent parallel advance between the study of astronomy and that of physics. He thinks the Yerkes Observatory will have served a good purpose if it shall bring these two lines of study into still closer relations to each other, enforcing this view by recent instances of the mutual aid rendered in the study of helium especially. He then called attention to points of interest pertaining to the 40-inch refractor. First, its great resolving power, claiming that the telescope is powerful enough to separate double stars about one tenth of a second of arc apart. It was said that Professor Barnard had used on the telescope a power of 3,750 diameters, and with such power he had obtained an image good enough for a measure by the position micrometer. The theoretical limit of a 40-inch glass for useful magnification is 4,000 diameters. It would appear from the above statement, that the glass has excellent resolving power. Four or five new difficult double stars have been discovered, and twenty exceedingly faint nebulæ have been found by Mr. Barnard. He has also seen the Hind nebula which was presumably so faint as to be beyond the reach of any telescope. Some other instances of the definining power of the great instrument were mentioned and commented on in this connection, but the above examples are sufficient to illustrate the point made by the speaker in regard to what has already been seen in the few weeks of use since the completion of its mounting. The astronomers of the Observatory feel sure that the great telescope will add much to our present knowledge in many directions which will be useful in solving some problems in astronomy, though it may not enable us to say whether the Moon is inhabited or not, still less the planet Mars, yet it will furnish the means of more accurate computations of comet orbits, because the comet can be watched through a larger portion of its path, may reveal the existence of other satellites and stars than those now known, settle the question of the rotation time of the planets Mercury and Venus, and possibly also that of the satellites of Jupiter.

Under the head of light-gathering power which is of so much value in difficult astronomical research, a comparison was made with the Lick telescope at Mount Hamilton, California, the di-

ameter of that glass being 36 inches. The ratio of the surface areas of the two glasses is as 81 to 100, nearly as 4 to 5 a gain of more than 20 per cent. This important fact tells almost more than any other single one in regard to what the great glass of the Yerkes telescope ought to do under favorable circumstances. Another fact of unusual interest is the quality of the Yerkes glass in regard to the absorption of light that passes through it. It was claimed by the speaker that nearly 28 per cent of the light that falls on the exterior surface of the objective is lost by reflection and absorption, so that about 72 per cent is available for use. Although the glass is so much larger than the Lick objective it is claimed that the loss of light is something less. It will be interesting to learn just how this last named fact was ascertained.

It was also a surprise to some of the visitors that the location of the Observatory at so low an altitude as that of the banks of Lake Geneva should give such promise of high quality for observing purposes. The experience of some of the observers now at work at the Yerkes Observatory is long enough and certainly varied enough in this particular to give reliable information on the much mooted question of altitude for high grade astronomical work. This matter also will be followed with interest, for the belief has, in recent time past been in favor of considerable altitudes for the best results.

A considerable time in the afternoon of Tuesday (and at other times as well) was devoted to the examination of the shops belonging to the Observatory, under the guidance of Professor F. L. O. Wadsworth and his assistants. These shops occupy a portion of the basement of the Observatory building and seem to be provided with ample room and light for the work to be done in them. The two lines of work provided for are the mechanical and the optical. Considerable machinery needed for the first kind is already in place with the electrical power necessary to propel it, and the same was seen in operation.

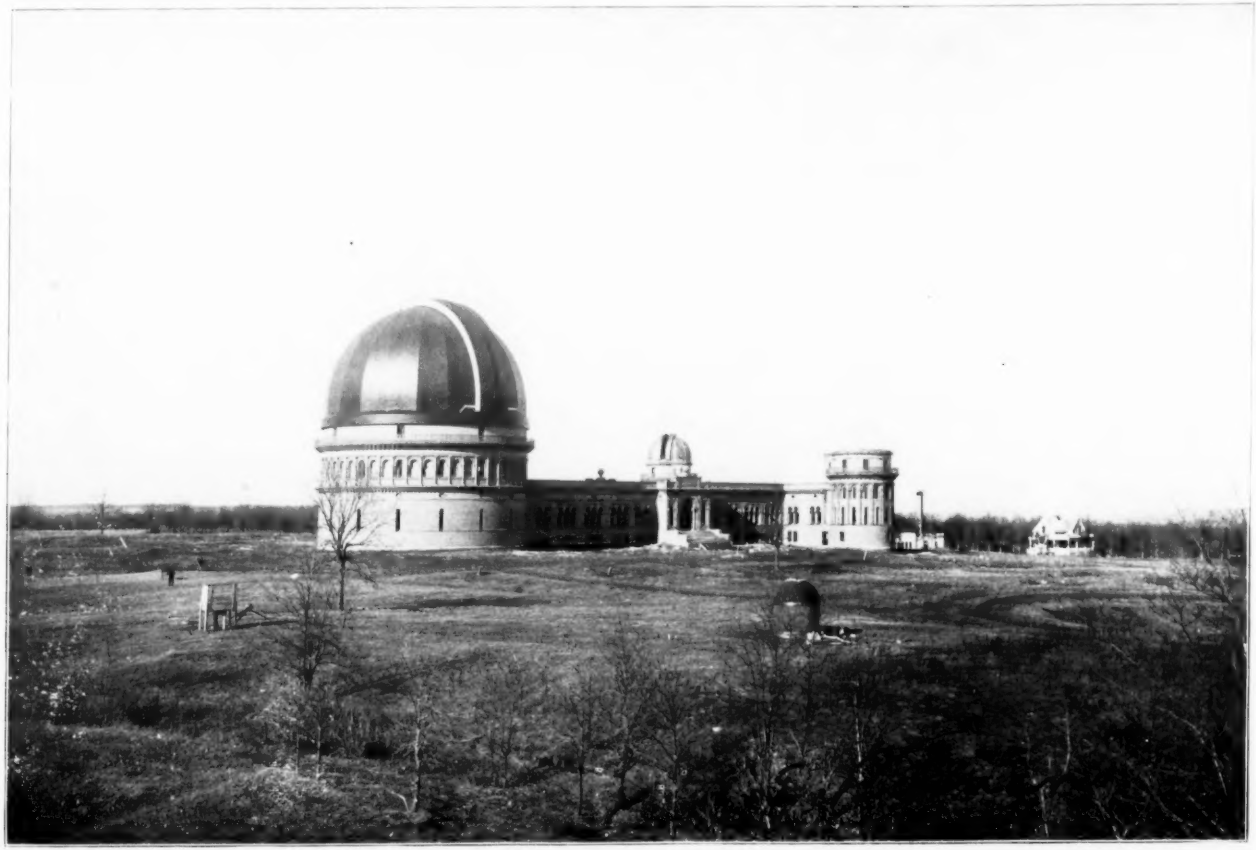
Some of the apparatus for grinding lenses was also exhibited and a large piece of plate glass five feet in diameter was in place to show how the optical machinery is applied to grind the curves wanted to make a lens or a mirror. The particular piece of glass referred to will be made into a mirror if the grinding is successful. Some of the tools to be used in making the necessary curves were exhibited, others are yet to be made in the mechanical shop. The instruments in process of construction, are an equatorial mounting for a 24-inch reflector, by the aid of Mr. Ernest Lorenz, me-

chanician, spectroheliograph for 40-inch telescope, Mr. Joseph Kathan, mechanician, a ruling machine for optical gratings, Mr. George C. Mors, mechanician.

Professor Henry Crew, of the Northwestern University, exhibited a piece of apparatus designed for the production of the spectrum of the metallic arc. The interesting features about this new machine are, that a piece of metal in the form of a disk is set in rapid motion and crowded steadily against another substance, which by the aid of a current of electricity produce a strong and quite steadily continuous arc of light containing of course the vapor of the metal in motion. The strong light of this arc is received by the slit of the grating spectroscope, and the spectrum of the particular metal in question is beautifully and strikingly presented to the eye of the observer at the view telescope. The ready and the independent way in which this piece of apparatus was used in the hands of Professor Crew would lead a visitor to believe that it would be very useful in the physical laboratory in the production and study of the metallic spectra.

There were two other pieces of apparatus on exhibition which received general attention. They were those used for testing the figure of lenses. One belonged to the Yerkes Observatory and the other to Mr. Charles A. Lundin, now in charge of the optical works of the late Alvan Clark, Cambridge, Mass. Mr. Lundin had brought his apparatus from Cambridge to this conference, by invitation, for the purpose of showing the manner in which the Clarks have done this delicate work for years past. The illustrations given by both pieces of apparatus were very satisfactory.

In the evening some disappointment was visibly shown in the faces of the visitors in consequence of a clouded sky, at the time of promised views of certain celestial objects by the aid of the great 40-inch telescope. Later, however, the sky cleared, and nearly all present had an opportunity of viewing the new Merope nebula which envelops the star of the Pleiades cluster having the same name. This beautiful object we had never seen before. The old large nebula about the same star bearing the same name has always been considered difficult of observation by any telescope except those of large aperture, but easy enough to photograph by small telescopes. The old nebula, because of its faintness had been the subject of much discussion until a few years ago when photography placed its existence beyond a doubt and its place in relation to the star Merope beyond any question. But this new nebula is now a matter of great interest and its relation to the apparently involved star and also to the old nebula will be studied with interest.



YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO, WILLIAMS' BAY, WIS.

REDUCED FROM NO. 43.

After this single view in a state of seeing not favorable, the sky was again overcast and further observation for the night was abandoned.

Wednesday, October 20, was a very full day. It was the last day of the sessions of the conference, and every hour was usefully employed. We can give only a meager report of its proceedings, because so much was done, and also because space at command is limited.

Among the papers of special interest was that of Professor Carl Runge, director of the spectroscopic laboratory Technische Hochschule Hanover, Germany, on Oxygen in the Sun. He gave a brief history of the attempts of physicists to determine this matter, giving also some attention to the laws governing certain lines of the spectra of some substances showing the orderly way in which they are related. He noticed the mistake that Jewell had made in regard to the so-called atmospheric lines of the solar spectrum. In Professor Runge's belief there is evidence by the spectroscope that oxygen exists in the Sun.

The paper by Dr. J. W. Humphreys, University of Virginia, on the effect of pressure on wave-lengths was a clear presentation of recent studies in this important field. The result of this work has already been referred to in this magazine, as may be seen on page 334 of the October number. These results are so important that they will clearly influence astronomical work in determining the velocity of stellar motions in line of sight, and possibly have to do with information to be gained relating to atmospheric pressure on the surfaces of the stars.

Dr. Charles Lane Poor, associate professor of astronomy, Johns Hopkins University, presented a paper, on a new form of mirror for reflecting telescopes. The form of the mirror considered was that of a paraboloid with the central part removed. By means of drawings the operation of this kind of mirror was explained, and the advantages of it for the observer were claimed to be great. If the elbow form of mounting should be used Mr. Poor thought that the observer could always occupy one position while at work, and that there was no good reason why the observing room might not be conveniently warm, both of which things he thought helpful to the best results. The point of greatest difficulty in procuring such a mirror would be to grind it. He had anticipated that draw-back and he explained how it might be overcome. The paper awakened general interest.

Professor Simon Newcomb, of Washington, D. C., spoke briefly on solar motion and stellar parallax. The direction and amount

of the motion of the Sun in space is still a problem of great difficulty to solve because the data for it are insufficient. We need more knowledge of stellar motion and stellar parallax. The knowledge of the motions of a few stars in the line of sight will not be sufficient. We need such data concerning the great mass of stars. The mean motion of all the stars would give the evidence needed. From a study of the small stars in zones the appearance is that the stellar universe is limited in extent, and that the individuals of the small stars are really less in size than those which are apparently large and near us.

John T. Hederick, S. J., Georgetown College Observatory, presented the way star transits are observed by means of a photochronograph. The instrument was shown during the description and photographs of its work exhibited. This method of observing has been in use some little time at the Georgetown Observatory during which important improvements in the apparatus have been made. The apparatus does away with the errors of the personal equation which are troublesome in the ordinary way of observing.

Professor H. S. Pritchett, Director of the Observatory at Washington University, St. Louis, Mo., gave a paper on the personal equation in longitude determination. Professor Pritchett has been for many years engaged in longitude work in the southwest, and so was able to give results gained from much experience in this kind of work. In determining a longitude of any place from his Observatory, the first step is to have the longitude between two piers, eight feet apart, in his own Observatory determined by the two observers with all the care and detail later to be used by the same persons in the field. The point brought out by Professor Pritchett was, that the personal equation in determining a longitude of eight feet was identically the same as that found in getting a longitude of 1500 miles. This was said to be verified by many different determinations during past years.

J. G. Hagan, S. J., of Georgetown College Observatory described the atlas of variable stars which he is now making in a very clear and interesting manner. He pointed out the obstacles he had met in the way of devising an accurate system for the chart, and gave his reasons for deciding to pursue the particular plan which he had chosen. The views which he presented as to the best way of doing this new kind of work seemed to meet with general approval and some words of hearty commendation by prominent members of the conference followed the paper. The burden of printing these charts has been generously assumed by

Miss Catharine Bruce, of New York City, whose name for good deeds in aid of astronomy is becoming a house hold word. In commenting on this paper Professor E. C. Pickering, of Harvard, saw no reason why the variable stars of this chart might not be carried down to the 12½ or 13 magnitude accurately. Variable star observers will soon have the aid of a very useful chart for reference in this new branch of astronomy.

Professor G. W. Myers, Director of the Observatory of the University of Illinois presented a paper on the system of β Lyræ. He began by giving some history of the theories of light variation and the various methods adopted for the explanation of the same, making more prominent the eclipse theory than others, as this theory was the basis of his paper, which was more severely mathematical than any other presented at the conference. The paper was also admirably worked out to the limit of reasonable supposition in many directions so that the ready analyst would feel satisfied to speak of it as fairly reasonable, using all known data to full face value in deriving a theory for the light variation of this well known variable system. The visitors were aided in following the mathematical discussion of the various hypotheses to account for the irregular light variation of the star system by large blue print sheets provided by Professor Myers in number sufficient to accommodate nearly all present, which contained all the principal steps in the analysis with the equations of reduction placed near the geometrical figures to which each set applied.

It would be very unsatisfactory to any one interested in this masterly paper for us to attempt an analysis of its matter or methods at this time and under these circumstances. We much prefer to have Professor Myers favor our readers with a popular or semi popular, presentation of the substance of it in an article especially prepared for this publication which will fully supply what is lacking in this brief notice.

Professor C. L. Doolittle, director of Flower Observatory, University of Pennsylvania, gave a paper on the latitude work of that Observatory. After description of his new instruments, cuts of which have been shown in this publication (No. 43, July last.) The method of work pursued in the determination of latitude was fully described. The stars chosen were divided into four groups of ten pairs each.

First group was in right ascension between							5^h	28^m	and	7^h 9^m
Second	"	"	"	"	"	"	12	48	and	14 52
Third	"	"	"	"	"	"	17	19	and	19 16
Fourth	"	"	"	"	"	"	21	29	and	23 22

A detailed statement was made as to the advantages and disadvantages of the particular stars chosen. The so-called Talcott method of work was used and observations began Oct. 1, 1896, and reductions have been made to August 26, 1897. The results obtained at intervals according to dates given below are as follows:

Date.	Lat. of Obs'y.
	° ′ ″
Oct. 16, 1896,	29 58 1.91
Nov. 14	1.86
Dec. 28	2.08
Feb. 5, 1897,	2.14
April 4	2.26
May 14	2.26
May 28	2.25
June 16	2 25
July 18	2 22
Aug. 14	2 27(?)

In the course of reduction the probable error of observation in the several groups of stars was as follows: Group 1, 0″.135; Group 2, 0″.139; Group 3, 0″.137 and Group 4, 0″.142. The series of results given above is interesting in the gradual change shown as the work progressed, except that given under Aug. 14. For that date it was said work was less favorable in some particulars. In these results is there not a suggestion at least of a change of latitude? It will be interesting to compare later results with these, if the work is continued, so as to know if the results of corresponding times in different years show a period of change of the pole of the Earth as announced by Dr. Chandler of Cambridge, Mass.

Professor J. K. Rees, Director of the Observatory of Columbia College, New York City, gave a paper on the variation of latitude and the reduction of the Rutherfurd photographs. For the study of the problem of the variation of latitude arrangement was made some time ago, between the Royal Observatory of Naples and the Observatory at Columbia College for simultaneous observations of a chosen list of stars for this purpose. The results obtained in 1893 and 1894 showed a change of latitude of about one tenth of a second of arc, the reductions at both places being in close agreement.

In the work of measuring the Rutherfurd photographs, Professor Jacoby, Dr. Davis and Professor Rees have participated. It was noted that the measures of the photographs of the Pleiades had given results comparable with the heliometer work of triangulation already published. The new Repsold machine had given measures of plates taken in 1872 with nearly the same degree of accuracy as was found in the measures made by Mr. Ruth-

erfurd when the plates were new by the machine made by himself for this purpose. Plates more than twenty years old had not seriously deteriorated except in a few instances.

Professor G. W. Hough, director of Dearborn Observatory of the University at Evanston, by the aid of the stereopticon and slides gave a full account of his study pertaining to the surface markings of the planet Jupiter for nearly a score of years past. The address was instructive to all because Professor Hough is an authority in this matter.

Professor E. E. Barnard, of the Yerkes Observatory, by means of the stereopticon presented a great number of his admirable photographs of the regions of the Milky Way accompanying the same by explanations to bring out new and important features that his pictures show. We have seen nothing that equals his photographic work in these rich star fields.

Professor E. C. Pickering, of Harvard College Observatory, also, by aid of the steriopticon, presented some of the rare work that his Observatories at Cambridge, Mass., and Arequipa, Peru, are doing. The wonderful results gained by the photography of the spectrum of the stars was most happily shown in the ready and lucid way in which he speaks. The spectra of those binaries which are beyond the reach of the most powerful visual telescopes, were pictures of great interest. To see the lines of the spectrum so separated or superposed as a consequence of the motion of the components of a binary star was an evidence of instrumental power in stellar research as convincing in fact as it was astonishing in reality. Professor Newcomb's estimate of the work of Harvard College Observatory is a just tribute to its merit.

Dr. Curt Laves of the University of Chicago gave a brief paper on the perturbations of the minor planet Chicago by Jupiter as the disturbing planet. The results obtained were highly interesting and in some respects novel so far as we now remember in regard to similar facts pertaining to the perturbations of other asteroids. Dr. Laves in the near future will favor our readers with an account of this work.

There were several other papers and exercises in connection with this series of admiraqle meetings that we are unable to present at this time.

Thursday was set apart for the dedicatory exercises of the Observatory and early in the morning preparations were in progress for this important occasion. Mr. Charles T. Yerkes, of Chicago, whose name the Observatory bears, came to the building Wednesday afternoon and examined it somewhat in detail, and ex-

pressed himself as pleased with all that he saw. A very large number of invited guests came by two excursion trains from Chicago arriving at the Observatory building about eleven o'clock. The procession formed in the main corridor and marched to the dome room of the 40-inch telescope, and it was said that about 800 people were seated in chairs on the movable floor of the dome room which is a circle about 90 feet in diameter. The spacious room was not crowded, apparently one-third as many more people could have been accommodated easily. Those to participate in the exercises and the guests of honor were seated on a raised platform near the wall opposite the entrance.

The opening exercises consisted of music by the Spiering Band, prayer by Rev. James D. Butler of Madison University, and introductory remarks by President William R. Harper. Then followed the address by Professor James E. Keeler of Allegheny Observatory, "On the importance of Astrophysical research and the relation of astrophysics to other physical sciences." He began by speaking of the boundaries of the physical sciences as not being sharply defined, but that they pass into one another by imperceptible gradations, so that often the common ground between two allied branches is so broad and fertile that a new science is developed for its special cultivation. Such is the nature of the new science which has been called the "New Astronomy or Astrophysics." This branch seeks to ascertain the nature of the heavenly bodies, rather than their positions or motions in space,—what they are rather than where they are. Special prominence is given to the study of radiation and the analysis of white light.

The rapidity of the growth of the new science is great. In the time of Sir John Herschel, only fifty years ago, it was supposed that the existence of great phosphorescent organisms on the Sun's surface was possible. That view compared with present knowledge of the sources of the Sun's light indicates rapid advancement.

A real basis for the science was laid by the invention of the spectroscope, and it was claimed that astrophysics has less direct bearing on the practical affairs of every day life than the older astronomy, but both sciences have a sufficient justification in the fact that they enable us better to understand the universe of which we form a part.

There is diversity of opinion as to the exact value of astrophysical research, because the science is new, and its bearing on other sciences is not yet fully known; but important results have fol-

lowed one another so rapidly that public attention has been drawn to spectroscopy very generally, and large expectations have been raised as to what the new science shall bring forth in the future. It is certain that whatever shall be realized in the advancement of this science will be shared by the older astronomy as well.

Professor Keeler then spoke of other advantages of the new method of study as derived from its achievements of the past, also of its application to hard solar problems and others in science awaiting this, or some other means competent to their solutio... His svrvey of the field of science as it now claims the attention of scholars was very complete and highly instructive. A fuller review of this able address is deserved, but space for it is lacking now.

THE ASPECTS OF AMERICAN ASTRONOMY.*

"The University of Chicago yesterday accepted one of the most munificent gifts ever made for the promotion of any single science and with appropriate ceremonies dedicated it to the increase of our knowledge of the heavenly bodies.

"The President of your University has done me the honor of inviting me to supplement what was said on that occasion by some remarks of a more general nature suggested by the celebration. One is naturally disposed to say first what is uppermost in his mind. At the present moment this will naturally be the general impression made by what has been seen and heard. The ceremonies were attended, not only by a remarkable delegation of citizens, but by a number of visiting astronomers, which must be considered large when we consider that the profession itself is not at all numerous in any country. As one of these, your guests, I am sure that I give expression only to their unanimous sentiment in saying that we have been extremely gratified in many ways by all that we have seen and heard. The mere fact of so magnificent a gift to science cannot but excite universal admiration. We knew well enough that it was nothing more than might have been expected from the public spirit of this great West; but the first view of a towering snow peak is none the less impressive because you have learned in your geography how many feet high it is, and great acts are none the less admirable

* Address delivered by Professor Simon Newcomb of Washington, D. C., at the Dedication of the Yerkes Observatory in the Kent Theater of the University of Chicago, Friday, October 22, 1897.

because they correspond to what you have heard and read, and might therefore be led to expect.

"The next gratifying feature is the great public interest excited by the occasion. That the opening of a purely scientific institution should have led so large an assemblage of citizens to devote an entire day, including a long journey by rail, to the celebration of yesterday is something most suggestive from its unfamiliarity. A great many scientific establishments have been inaugurated during the last half century, but if on any such occasion so large a body of citizens has gone so great a distance to take part in the inauguration the fact has at the moment escaped from our minds.

"That the interest thus shown is not confined to the hundreds of attendants, but must be shared by your great public, is shown by the unfailing barometer of journalism. Here we have a field in which the non-survival of the unfit is the rule in its most ruthless form; the journals that we see and read are merely the fortunate few of a countless number, dead and forgotten, that did not know what the public wanted to read about. The eagerness shown by the representatives of your press in recording everything your guests would say was accomplished by an enterprise in making known everything that occurred and, in case of an emergency requiring a heroic measure, what did not occur, showing that smart journalists of the east must have learned their trade, or at least breathed their inspiration in these regions. I think it was some twenty years since I told a European friend that the eighth wonder of the world was a Chicago daily newspaper. Since that time the course of journalistic enterprise has been in the reverse direction, and the course of empire eastward, instead of westward.

"It is sometimes said—wrongfully, I think—that scientific men form a mutual admiration society. One feature of the occasion made me feel that we, your guests, ought then and there to have organized such a society, and forthwith proceeded to business—this feature consisted in the conferences on almost every branch of astronomy by which the celebration of yesterday was preceded The fact that beyond the acceptance of a graceful compliment I contributed nothing to these conferences relieves me from the charge of bias or self-assertion in saying that they gave me a new and most inspiring view of the energy now being expended in research by the younger generation of astronomers. All the experience of the past leads us to believe that this energy will reap the reward which nature always bestows upon those who

seek her acquaintance from unselfish motives. In one way it might appear that little was to be learned from a meeting like that of the present week—each astronomer may know by publications pertaining to the science what all the others are doing; but this knowledge, obtained in this way, has a sort of abstractness about it a little like our knowledge of the progress of civilization in Japan, or of the great extent of the Australian continent. It was, therefore, a most happy thought on the part of your authorities to bring together the largest possible number of visiting astronomers from Europe as well as America, in order that each might see, through the attrition of personal contact, what progress the others were making in their researches. To the visitors at least I am sure that the result of this meeting has been extremely gratifying. They earnestly hope, one and all, that the callers of this conference will not themselves be more disappointed in its results; that however little they may have actually to learn of methods and results, they will feel stimulated to well directed efforts and find themselves inspired by thoughts which, however familiar, will now be more easily worked out.

"We may pass from the aspects of the case as seen by the more strictly professional class to those more general aspects fitted to excite the attention of the great public. From the point of view of the latter it may well appear that the most striking feature of the celebration is to be found in the great amount of effort which it shows to be devoted to the cultivation of a field quite outside of the ordinary range of human interests. A little more than two centuries ago Huyghens prefaced an account of his discoveries on the planet Saturn with the remark that many, even among the learned, might think he had been devoting to things too distant to interest mankind an amount of study which would better have been devoted to subjects of more immediate concern. It must be admitted that this fear has not deterred succeeding astronomers from pursuing their studies. The enthusiastic students whom we see around us are only a detachment from an army of investigators who, in many parts of the world, are seeking to explore the mysteries of creation. Why so great an expenditure of energy? Certainly not to gain wealth, for astronomy is perhaps the one field of scientific work, which in our expressive modern phrase, 'has no money in it.' It is true that the great practical use of astronomical science to the country and

the world in affording us the means of determining positions on land and at sea is frequently pointed out. It is said that an Astronomer Royal of England once calculated that every meridian observation of the Moon made at Greenwich was worth a pound sterling, on account of the help it would ultimately afford to the navigation of the ocean. An accurate map of the United States cannot be constructed without astronomical observations at numerous points scattered over the whole country, aided by data which great Observatories have been accumulating for more than a century, and must continue to accumulate in the future.

"But neither the measurement of the Earth, the making of maps, nor the aid of the navigator is the main object which the astronomers of to-day have in view. If they do not quite share the sentiment of that eminent mathematician, who is said to have thanked God that his science was one which could not be prostituted to any useful purpose, they still know well that to keep utilitarian objects in view would only handicap them in their work. Consequently, they never ask in what way their science is going to benefit mankind.

"As the great captain of industry is moved by the love of wealth and the politician by the love of power, so the astronomer is moved by the love of knowledge for its own sake, and not for the sake of its application. He is proud to know that his science has been worth more to mankind than it has cost. He does not value its results merely as a means of crossing the ocean or mapping the country, for he feels that man does not live by bread alone. If it is not more than bread to know the place we occupy in the universe, it is certainly something which we should place not far behind the means of subsistence. That we now look upon a comet as something very interesting, of which the sight affords us a pleasure unmixed with fear of war, pestilence or other calamity, and of which we therefore wish the return, is a gain that we cannot measure by money. In all ages astronomy has been an index to the civilization of the people who cultivate it. It has been crude or exact, enlightened or mingled with superstition, according to the current mode of thought. When once men understand the relation of the planet on which they dwell to the universe at large superstition is doomed to speedy extinction. This alone is an object worth more than money.

"Astronomy may fairly claim to be that science which transcends all others in its demands upon the practical application of our reasoning powers. Look at the stars that stud the heavens on a clear evening. What more hopeless problem to one confined

to earth than that of determining their varying distances, their motions and their physical constitution? Everything on earth we can handle and investigate. But how investigate that which is ever beyond our reach, on which we can never make an experiment? On certain occasions we see the Moon pass in front of the Sun and hide it from our eyes. To an observer a few miles away the Sun was not entirely hidden, for the shadow of the Moon in a total eclipse is rarely 100 miles wide. On another continent no eclipse at all may have been visible. Who shall take a map of the world and mark upon it the line on which the Moon's shadow will travel during some eclipse a hundred years hence? Who shall map out the orbits of the heavenly bodies as they are going to appear in a hundred thousand years? How shall we ever know of what chemical elements the Sun and the stars are made? All this has been done, but not by the intellect of any one man. The road to the stars has been opened only by the efforts of many generations of mathematicians and observers, each of whom began where his predecessor had left off. We have reached a certain stage where we know much about the heavenly bodies.

"We have mapped out our solar system with great precision. But how with that great universe of millions of stars in which our solar system is only a speck of star dust, a speck which a traveler through the wilds of space might pass a hundred times without notice? We have learned much about this universe, though our knowledge of it is still dim. We see it as a traveler on a mountain top sees a distant city in a cloud of mist, by a few specks of glimmering light, from steeples or roofs. We want to know more about it, its origin and its destiny; its limits in time and space, if it has any; what function it serves in that universal economy. The journey is long, yet we want, in knowledge at least, to reach the stars. Hence we build Observatories and train observers and investigators. Slow indeed is progress in the solution of the greatest of problems, when measured by what we want to know. Some questions may require centuries, others thousands of years for their answer. And yet never was progress more rapid than during our time. In some directions our astronomers of today are out of sight of those of fifty years ago; we are even gaining heights which twenty years ago looked hopeless. Never before had the astronomer so much work, good, hard, yet hopeful work, before him as today. He who is leaving the stage feels that he has only begun, and must leave his successors with more to do than his predecessors left him.

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"To us an interesting feature of this progress is the part taken

in it by our own country. Our traditional reputation has not been that of a people deeply interested in the higher branches of intellectual work. Men yet living can remember when in the eyes of the universal church of learning all cisatlantic countries, our own included, were *partes infidelium*.

"Yet American astronomy is not entirely of our generation. In the middle of the last century Professor Winthrop of Harvard was an industrious observer of eclipses and kindred phenomena, whose work was recorded in the transactions of learned societies. But the greatest astronomical activity during our colonial period was that called out by the transit of Venus in 1769, which was visible in this country. A committee of the American Philosophical Society at Philadelphia organized an excellent system of observations, which we now know to have been fully as successful, perhaps more so, than the majority of those made on other continents, owing mainly to the advantages of air and climate. Among the observers was the celebrated Rittenhouse, to whom is due the distinction of having been the first American astronomer whose work has an important place in the history of the science. In addition to the observations which he has left us, he was the first inventor or proposer of the collimating telescope, an instrument which has become almost a necessity wherever accurate observations are made. The fact that the subsequent invention by Bessel was quite independent does not detract from the merits of either.

"Shortly after the transit of Venus, which I have mentioned, the war of the revolution commenced. The generation which carried on that war, and the following one which formed our constitution and laid the bases of our political institutions, were naturally too much occupied with these great problems to pay much attention to pure science.

"American astronomers must always honor the names of Rittenhouse and Bowditch. And yet, in one respect their work was disappointing of results. Neither of them was the founder of a school. Rittenhouse left no successor to carry on his work. The help which Bowditch afforded his generation was invaluable to isolated students who, here and there dived alone and unaided into the mysteries of the celestial motions. His work was not mainly in the field of observational astronomy, and therefore did not materially influence that branch of science. In 1832 Professor Airy, afterward Astronomer Royal of England, made a report to the British Association on the condition of practical astronomy in various countries. In this report he remarked that he

was unable to say anything about American astronomy because so far as he knew, no public Observatory existed in the United States.

"William C. Bond, afterward famous as the first director of Harvard Observatory, was at that time making observations with a small telescope, first near Boston, and afterward at Cambridge. But with so meager an outfit his establishment could scarcely lay claim to being an astronomical Observatory, and it was not surprising if Airy did not know anything of his modest efforts.

"If at this time Professor Airy had extended his investigations into yet another field, with a view of determining the prospects for a great city at the cite of Fort Dearborn, on the southern shore of Lake Michigan, he would have seen as little prospect of civic growth in that region as of a great development of astronomy in the United States at large. A plat of the proposed town of Chicago had been prepared two years before, when the place contained perhaps a half a dozen families. In the same month in which Professor Airy made his report, August, 1832, the people of that place, then numbering twenty-eight voters, decided to become incorporated, and selected five trustees to carry on their government.

"In 1837 a city charter was obtained from the legislature of Illinois. The growth of the infant city, then small even for an infant, into the great commercial metropolis of the West has been the just pride of its people and the wonder of the world. I mention it now because of a remarkable coincidence. With this civic growth has quietly gone on another, little noted by the great world, and yet in its way equally wonderful and equally gratifying to the pride of those who measure greatness by intellectual progress. If it be true that in nature nothing is great but man; in man nothing is great but mind; then may knowledge of the universe be regarded as the true measure of progress. I therefore invite attention to the fact that American astronomy began with your city, and has slowly but surely kept pace with it until to-day our country stands second only to Germany in number of researches being prosecuted, and second to none in number of men who have gained the highest recognition by their labors.

"In 1836 Professor Albert Hopkins of Williams College and Professor Elias Loomis of Western Reserve College, Ohio, both commenced little Observatories. Professor Loomis went to Europe for all his instruments, but Hopkins was even then able to get some of his in this country. Probably neither anticipated

the day when European investigators, in need of the most perfect instruments that human art could produce, would come to this side of the Atlantic for them. Shortly afterward a little wooden structure was erected by Captain Gilliss on Capitol Hill at Washington and supplied with a transit instrument for observing Moon culminations in conjunction with the work of Captain Wilkes, who was then setting out on his well-known exploring expedition to the southern hemisphere. The date of these Observatories was practically the same as that on which the charter for the City of Chicago was obtained from the legislature. With their establishment the population of your city had increased to 703.

"The next decade, 1840 to 1850, was that in which our practical astronomy seriously commenced. The little Observatory of Captain Gillis was replaced by the Naval Observatory, erected at Washington during the years 1843-4 and fitted out with what were then the most approved instruments. About the same time the appearance of the great comet of 1843 led the citizens of Boston to erect the Observatory of Harvard College. Thus it is little more than half a century since the two principal Observatories in the United States were established. But we must not for a moment suppose that the mere erection of an Observatory can mark an epoch in scientific history. What must make the decade of which I speak ever memorable in American Astronomy was not merely the erection of buildings, but the character of the work done by astronomers away from them as well as in them.

"The Naval Observatory very soon became famous by two remarkable steps which raised our country to an important position among those applying modern science to practical uses. One of these consisted of the researches of Sears Cook Walker on the motion of newly discovered planet Neptune. He was the first astronomer to determine fairly good elements of the orbit of that planet, and, what is yet more remarkable, he was able to trace back the movement of the planet in the heavens for half a century and to show that it had been observed as a fixed star by Lalande in 1795 without the observer having any suspicion of the true character of the object.

"The other work to which I refer was the application to astronomy and to the determination of longitudes of chronographic method of registering transits of stars or other phenomena requiring an exact record of the instant of their occurence. It is to be regretted that the history of this application has not been fully written. In some points there seems to be as much obscurity

as with the discovery of ether as an anæsthetic, which took place about the same time. Happily no such contest has been fought over the astronomical as over the surgical discovery—the fact being that all who were engaged in perfecting the application of the new method were more anxious to perfect it than they were to get credit for themselves. We know that Saxton of the Coast Survey, Mitchell and Locke of Cincinnati, Bond at Cambridge, as well as Walker and other astronomers at the Naval Observatory, all worked at the apparatus, that Maury seconded their efforts with untiring zeal, that it was used to determine the longitude of Baltimore as early as 1844 by Captain Wilkes, and that it was put into practical use in recording observations at the Naval Observatory as early as 1846.

"At the Cambridge Observatory the two Bonds, father and son, speedily began to show the stuff of which the astronomer is made. A well devised system of observations was put in operation. The discovery of the dark ring of Saturn and of a new satellite to that planet gave additional fame to the establishment.

"Nor was activity confined to the observational side of the science. The same decade of which I speak was marked by the beginning of Professor Pierce's mathematical work, especially his determination of the perturbations of Uranus and Neptune. At this time commenced the work of Dr. B. A. Gould, who soon became the leading figure in American astronomy. Immediately on graduating at Harvard in 1845, he determined to devote all the energies of his life to the prosecution of his favorite science. He studied in Europe for three years, took the doctor's degree at Gottingen, came home, founded the *Astronomical Journal*, and took an active part in that branch of the work of the Coast Survey which included the determination of longitudes by astronomical methods.

"An episode which may not belong to the history of astronomy must be acknowledged to have had a powerful influence in exciting public interest in that science. Professor O. M. Mitchell, the founder and first director of the Cincinnati Observatory, made the masses of our intelligent people acquainted with the leading facts of astronomy by courses of lectures which, in lucidity and eloquence, have never beer excelled. The immediate object of the lectures was to raise funds for establishing his Observatory and fitting it out with a fine telescope. The popular interest thus excited in the science had an important effect in leading the public to support astronomical research. If public

support, based on public interest, is what has made the present fabric of American astronomy possible, then should we honor the name of a man whose enthusiasm leavened the masses of his countrymen with interest in our science.

"The civil war naturally exerted a depressing influence upon our scientific activity. The cultivator of knowledge is no less patriotic than his fellow citizens, and vies with them in devotion to the public welfare. The active interest which such cultivators took, first in the prosecution of the war and then in the restoration of the Union, naturally distracted their attention from their favorite pursuits. But no sooner was political stability reached than a wave of intellectual activity set in, which has gone on increasing up to the present time. If it be true that never before in our history has so much attention been given to education as now; that never before did so many men devote themselves to the diffusion of knowledge, it is no less true that never was astronomical work so energetically pursued among us as now. One deplorable result of the civil war was that *Gould's Astronomical Journal* had to be suspended. Shortly after the restoration of peace, instead of re-establishing the Journal, its founder conceived the project of exploring the southern heavens. The northern hemisphere being the seat of civilization, that portion of the sky which could not be seen from our latitudes was comparatively neglected. What had been done in the southern hemisphere was mostly the occasional work of individuals and of one or two permanent Observatories. The latter were so few in number and so meager in their outfit that a splendid field was open to the inquirer. Gould found the patron which he desired in the government of the Argentine Republic, on whose territory he erected what must rank in the future as one of the memorable astronomical establishments of the world. His work affords a most striking example of the principle that the astronomer is more important than his instruments. Not only were the means at the command of the Argentine Observatory slender in the extreme when compared with the favored institutions of the north, but, from the very nature of the case, the Argentine Republic could not supply trained astronomers. The difficulties thus growing out of the administration cannot be overestimated. And yet the sixteen great volumes in which the work of the institution has been published will rank in the future among the classics of astronomy.

"Another wonderful focus of activity, in which one hardly knows whether he ought most to admire the exhaustless energy

or the admirable ingenuity which he finds displayed, is the Harvard Observatory. Its work has been aided by gifts which have no parallel in the liberality that prompted them. Yet without energy and skill such gifts would have been useless. The activity of the establishment includes both hemispheres. Time would fail to tell how it not only mapped out important regions of the heavens from the north to the south Pole, but analyzed the rays of light which come from hundreds of thousands of stars by recording their spectra in permanence on photographic plates.

"The work of the establishment is so organized that a new star cannot appear in any part of the heavens, nor a known star undergo any noteworthy change, without immediate detection by the photographic eye of one or more little telescopes, all seeing and never sleeping policemen, that scan the heavens unceasingly while the astronomer may sleep, and report in the morning every case of irregularity in the proceedings of the heavenly bodies.

"Yet another example, showing what great results may be obtained with limited means is afforded by the Lick Observatory of California. During the ten years of its activity its astronomers have made it known the world over by their unequalled works and discoveries, too varied and numerous to be even mentioned at the moment.

"The astronomical work of which I have thus far spoken has been almost entirely that done at Observatories. I fear that I may in this way have strengthened an erroneous impression that the seat of important astromical work is necessarily connected with an Observatory. It must be admitted that an institution which has a local habitation and a magnificent building commands public attention so strongly that valuable work done elsewhere may be overlooked. A very important part of astronomical work is done away from telescopes and meridian circles, and requires nothing but a good library for its prosecution. One who is devoted to this side of the subject may often feel that the public does not appreciate his work at its true relative value, from the very fact that he has no great buildings or fine instruments to show. I may therefore be allowed to claim as an important factor in the American astronomy of the last half-century an institution of which few have heard and which has been overlooked because there was nothing about it to excite attention.

"In 1849 the American Nautical Almanac office was established by a congressional appropriation. The title of this publication

is somewhat misleading in suggesting a simple enlargement of the family almanac which the sailor is to hang up in his cabin for daily use. The fact is that what started more than a century ago as a nautical almanac has since grown into an astronomical ephemeris for the publication of everything pertaining to times, seasons, eclipses and the motions of the heavenly bodies. It is the work in which astronomical observations made in all the great Observatories of the world are ultimately utilized for scientific and public purposes. Each of the leading nations of western Europe issues such a publication. When the preparations and publication of the American Ephemeris was decided upon the office was first established in Cambridge, the seat of Harvard University, because there could most readily be secured the technical knowledge of mathematics and theoretical astronomy necessary for the work.

"A field of activity was thus opened, of which a number of able young men who have since earned distinction in various walks of life availed themselves. Davis, the first superintendent, adopted a policy which, though widely at variance with a naval officer's ideas of discipline, was well calculated to promote the intellectual development of the one who had enlisted under him. For several years his office was a sort of informal school, not, indeed, of the modern type, but rather more like the classic grove of Hellas, where philosophers conducted their discussions and profited by mutual attrition. When, after a few years of experience, methods were well established and a routine adopted the office was removed to Washington, where it has since remained. The work of preparing the ephemeris has, with experience, been reduced to a matter of routine which may be continued indefinitely, with occasional changes in methods and data and improvements to meet the increasing wants of investigators.

"The mere preparation of the ephemeris includes but a small part of the work of mathematical calculation and investigation required in astronomy. One of the great wants of the science today is the re-reduction of the observations made during the first half of the present century, and even during the last half of the preceding one. The labor which could profitably be devoted to this work would be more than that required in any one astronomical Observatory. It is unfortunate for this work that a great building is not required for its prosecution, because its needfulness is thus very generally overlooked by that portion of the public interested in the progress of science. An organization especially devoted to it is one of the scientific needs of our time.

"In such an epoch-making age as the present it is dangerous to cite any one step as making a new epoch. Yet it may be that when the historian of the future reviews the science of our day he will find the most remarkable feature of the astronomy of the

last twenty years of our century to be the discovery that this steadfast earth of which the poets have told us is not alter all quite steadfast; that the North and South Poles move about a very little, describing curves so complicated that they have not yet been fully marked out. The periodic variations of latitude thus brought about were first suspected about 1880, and announced with some modest assurance by Küstner of Berlin a few years later. The progress of the views of astronomers generally fram incredulity to confidence was extremely slow until about 1890. Chandler of the United States by an exhaustive discussion of innumerable results of observations showed that the latitude of every point on the earth was subject to a double oscillation, one having a period of a year, the other of 427 days.

"Notwithstanding the remarkable parallel between the growth of American astronomy and that of your city, one cannot but fear that if a foreign observer had been asked only half a dozen years ago at what point in the United States a great school of theoretical and practical astronomy, aided by an establishment for the exploration of the heavens, was likely to be established by the munificence of private citizens, he would have been wiser than most foreigners had he guessed Chicago. Had this place been suggested to him I fear he would have replied that were it possible to utilize celestial knowledge for promoting earthly wealth here would be the most promising seat for such a school. But he would need to have been a little wiser than his generation to reflect that wealth is the basis of all progress in knowledge and the liberal arts, that it is only when men are relieved from the necessity of devoting all their energies to the immediate wants af life that they can lead intellectual lives, and that we should therefore look to the most enterprising commercial center as the likeliest seat for a great scientific institution.

"Now we have the school, and we have the Observatory, which we hope will in the near future do work that will cast luster on the name of its founder as well as on the astronomers who may be associated with it. You will, I am sure, pardon me if I make some suggestions on the subject of the future needs of the establishment. We want this newly founded institution to be a great success, to do work which shall show that the intellectual productiveness of your community will not be allowed to lag behind its material growth. The public is very apt to feel that when some munificent patron of science has mounted a great telescope under a suitable dome and supplied all the apparatus which the astronomer wants to use success is assured. But such is not the

case. The most important requisite, one more difficult to command than telescopes or Observatories, may still be wanting. A great telescope is of no use without a man at the end of it, and what the telescope may do depends more upon this appendage than upon the instrument itself. The place which telescopes and Observatories have taken in astronomical history are by no means proportional to their dimensions. Many a great instrument has been a mere toy in the hands of its owner. Many a small one has become famous. Twenty years ago there was here in your own city a modest little instrument which, judged by its size, could not hold up its head with the great ones even of that day.

"It was the private property of a young man holding no professional position and scarcely known to the public. And yet that little telescope is to-day among the famous ones of the world, having made memorable advances, I might almost say a new epoch, in the astronomy of double stars, and shown its owner to be a worthy successor of the Herschels and the Struves in that line of work. A hundred observers might have used the appliances of the Lick Observatory for a whole generation without finding the fifth satellite of Jupiter; without successfully photographing the cloud forms of the Milky Way; without discovering the extraordinary patches of nebulous light, nearly or quite invisible to the human eye, which fill some regions of the heavens.

"When I was in Zurich last year I paid a visit to the little but not unknown Observatory of its famous polytechnic school. The professor of astronomy was especially interested in the observations of the Sun with the aid of the spectroscope, and among the ingenious devices which he described, not the least interesting was the method of photographing the Sun by special rays of the spectrum which had been invented at the Kenwood Observatory in Chicago. The Kenwood Observatory is not, I believe, in the eye of the public one of the noteworthy institutions of your city which every visitor is taken to see, and yet this invention has given it an important place in the science of our day.

"Should you ask me what is the most hopeful features in the great establishment which you are now dedicating I would say that they are not alone to be found in the size of your unequaled telescope, nor in the cost of the outfit, but in the fact that your authorities have shown their appreciation of the requirements of success by adding to the material outfit of the establishment the three men whose works have done such as I have described.

"Gentlemen of the trustees, allow me to commend to your fos-

tering care the men at the end of the telescope. The constitution of the astronomer shows curious and interesting features. If he is destined to advance the science of works of real genius he must, like the poet, be born, not made. The born astronomer, when placed in command of a telescope, goes about using it as naturally and effectively as the babe avails itself of its mother's breast. He sees intuitively what less gifted men have to learn by long study and tedious experiment. He is moved to celestial knowledge by a passion which dominates his nature. He can no more avoid doing astronomical work, whether in the line of observations or research, than the poet can chain his Pegasus to Earth. I do not mean by this that education and training will be of no use to him. They will certainly accelerate his early progress. If he is to become great on the mathematical side, not only must his genius have a bend in that direction, but he must have the means of pursuing his studies. And yet I have seen so many failures of men who had the best instruction, and so many successes of men who scarcely learned anything of their teachers, that I sometimes ask whether the great American celestial mechanician of the twentieth century will be a graduate of a university or of the backwoods.

"Is the man thus moved to the exploration of nature by an unconquerable passion more to be envied or pitied? In no other pursuit does success come with such certainty to him who deserves it. No life is so enjoyable as that whose energies are devoted to following out the inborn impulses of one's nature. The investigator of truth is little subject to the disappointments which commonly await the ambitious man in other fields of activity. It is pleasant to be one of a brotherhood extending over the world, in which no rivalry exists except that which comes out of trying to do better work than anyone else, while mutual admiration stifles jealousy. And yet, with all these advantages, the experience of the astronomer may have its dark side. As he sees his field widening faster than he can advance he is impressed with the littleness of all that can be done in one short life. He feels the same want of successors to pursue his work that the founder of a dynasty may feel for heirs to occupy his throne. He has no desire to figure in history as a Napoleon of science whose conquests must terminate with his life. Even during his active career his work may be of such a kind as to require the co-operatian of others and the active support of the public. If he is disappointed in commanding these requirements, if he finds neither co-operation nor support, if some great scheme to which he may have de-

voted much of his life thus proves to be only a castle in the air, he may feel that nature has dealt hardly with him in not endowing him with passions like to those of other men.

"In treating a theme of perennial interest one naturally tries to fancy what the future may have in store. If the traveler who views the ruins of some ancient city which in the long ago teemed with the life and activities of generations of men sees every stone instinct with emotion and the dust alive with memories of the past, may he not be similarly impressed when he feels that he is looking around upon a seat of future empire; a region where generations yet unborn may take a leading part in molding the history of the world? What may we not expect of that energy which in sixty years has transformed a straggling village into one of the world's great centres of commerce? May it not exercise a powerful influence on the destiny not only of the country but of the world? Shall the power thus to be exercised prove an agent of the beneficence, diffusing light and life among nations, or shall it be the opposite?

"The time must come ere long when wealth shall outgrow the field in which it can be profitably employed. In what direction shall its possessors then look? Shall they train a posterity which will so use its power as to make the world better that it has lived in it? Will the future heir to great wealth prefer the intellectual life to the life of pleasure?

"We can have no more hopeful answer to these questions than the establishment of this great University in the very focus of the commercial activity of the West. Its connection with the institution we have been dedicating suggests some thoughts on science as a factor in that scheme of education best adapted to make the power of a wealthy community a benefit to the race at large. When we see what a factor science has been in our present civilization, how it has transformed the world and increased the means of human enjoyment by enabling men to apply the powers of nature to their own uses, it is not wonderful that it should claim the place in education hitherto held by classical studies. In the contest which has thus arisen I take no part but that of a peacemaker, holding that it is as important to us to keep in touch with the traditions of our race and to cherish the thoughts which have come down to us through the centuries as it is to enjoy and utilize what the present has to offer us. Speaking from this point of view, I would point out the error of making the utilitarian applications of knowledge the main object in its pursuit. It is a historic fact that abstract science, science pursued without any util-

itarian end, has been at the basis of our progress in the application of knowledge. If in the last century such men as Galvani and Volta had been moved by any other motive than love of penetrating the secrets of nature they would never have pursued the seemingly useless experiments they did, and the foundation of electrical science would never have been laid. Our present applications of electricity did not become possible until Ohm's mathematical laws of the electric current, which when first made known seemed little more than mathematical curiosities, had become the common property of inventors. Professional pride on the part of our own Henry led him, after making the discoveries which rendered the telegraph possible, to go no further in the application of his discoveries, and to live and die without receiving a dollar of the millions which the country has won through his agency.

"In the spirit of scientific progress thus shown, we have patriotism in its highest form; a sentiment which does not seek to benefit the country at the expense of the world, but to benefit the world by means of one's country. Science has its competition, as keen as that which is the life of commerce. But its rivalries are over the question who shall contribute the most and the best to the sum total of knowledge, who shall give the most, not who shall take the most. Its animating spirit is love of truth. Its pride is to do the greatest good to the greatest number. It embraces not only the whole human race but all nature in its scope.

The public spirit of which this point is the focus has made the desert blossom as the rose, and benefited humanity by the diffusion of the material product of the Earth. Should you ask me how it is in the future to so use the influence thus acquired for the benefit of humanity at large, I would say, look at the work now going on in these precincts, and study its spirit. There are the agencies which will make 'the voice of law the harmony of the world.' Here is the love of country blended with the love of the race. Here the love of knowledge is as unconfined as your commercial enterprise. Do not think that the main object here is to learn the forms of vertebrates and the properties of oxides, but rather to imbibe that catholic spirit which, animating your energies, shall make your power an agent of beneficence to all mankind."

SOLAR ECLIPSES.—(*Concluded.*)

J. MORRISON, M. A., M. D., PH. D.

FOR POPULAR ASTRONOMY.

When all the circumstances of an eclipse are required, such for instance, as those given in Nautical Almanacs, Bessel's method is decidedly the best although it involves a very considerable amount of labor. The computation of the Besselian elements and of the auxiliary quantities ρ_1, ρ_2, d_1, d_2, a', b', c', e, f, E and F should be made with great care and with seven figure logarithms, except in the case of ρ_1 ρ_2 d_1 and d_2 where five figure tables will be sufficient. The Moon's parallax should be interpolated from the ephemeris to at least *two places* of decimals and should difference regularly and if it does not, it must be adjusted until it does do so, for any error here will be a disturbing factor throughout the entire computation. But when only a few of the circumstances of the eclipse are wanted—such as the dates and places of beginning or ending on the Earth generally, the place where the eclipse is central at any given time, where it is central at noon, etc.—the following method will be far more convenient, just as accurate and requires very little computation compared with the Besselian method.

An eclipse of the Sun first begins on the Earth generally when the Moon becomes tangent to the cone which envelopes the Sun and Earth. To the spectator this apparent contact will be in the horizon, the Moon's disk being wholly above and the Sun's below it, the point of contact and the centres of the Sun and Moon will evidently be in the same vertical circle and both bodies will be depressed by the horizontal parallaxes which at that time belong to that place. As the Sun's parallax is very small, it will be found most convenient to retain the Sun in his true place and to give to the Moon the effect of the difference of their parallaxes. This difference is that which influences the relative position of the two bodies and should be reduced to the place of observation, but since this is unknown, the least deviation from the truth will be obtained by reducing the difference of parallax to latitude 45°. If ρ_0 denote the radius of the Earth in latitude 45° and Π, the reduced relative parallax we shall have

$$\Pi = \rho_0 (\pi - \pi')$$

The places where the central eclipse (either total or annular) is first seen, is where the axis of the Moon's shadow first becomes

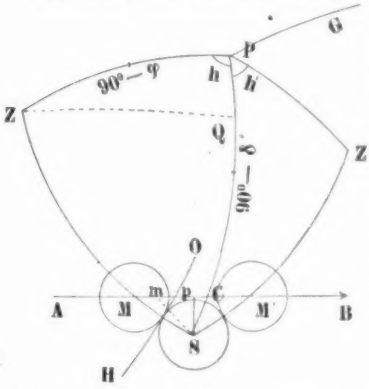
tangent to the Earth; the centres of the Sun and Moon will then be in the horizon.

Similar circumstances will evidently have place when the eclipse finally leaves the Earth. Let s and s' denote the semi-diameters of the Moon and Sun respectively and Δ, the angular distances between their centres as seen from the centre of the Earth, then it is evident we shall have the following limiting positions:

For beginning and ending on Earth generally $\Delta = \Pi + s + s'$
" " of total eclipse $\Delta = \Pi + s - s'$
" " of annular eclipse $\Delta = \Pi + s' - s$
" " of central eclipse $\Delta = \Pi$ (131)

The eclipse is of course total when $s > s'$ and annular when $s < s'$, provided internal contacts exist.

Referring the Sun and Moon to the surface of a sphere concentric with the Earth, let AB be a portion of the Moon's relative orbit or that which is generated by the relative motion of the Moon; P, the north pole; S the Sun; Sp a perpendicular to the relative orbit or the line of nearest approach of the centres; C the point where the Moon's comes into conjunction in R.A., CS being the difference of declination at that time; M and M' the positions of the Moon when the eclipse first begins and finally leaves the Earth, $MS = M'S = \Delta = \Pi + s + s'$, and Z and Z' the geocentric zeniths of the places where the eclipse is first and last seen and which must be in the continuations of SM and SM' respectively. HO is an arc of the horizon of the place whose zenith is Z and the direction of motion is indicated by the arrowhead.



ZS or $Z'S = 90° + s'$ but for practical purposes may be taken equal to 90° without any appreciable error and the Moon being so near the horizon will not be sensibly affected by augmentation.

Let φ' and φ'_1 be the *geocentric* latitudes of Z and Z' and h and h' the hour angles ZPS, $Z'PS$ and at the time of conjunction let

a = relative motion in R. A. *i. e.*, ☽'s motion in R. A. − ☉'s
d = " Decl., " " Decl. "
D = Difference of decl. at δ, *i. e.* ☽'s decl. − ☉'s decl.
i = inclination of relative orbit AB to a parallel of declination through C or the angle CSp.
v = angle MSp (this angle will be greater than 90° when D is negative)

NOTE.—The ′ mark on Z in the cut was omitted by engraver.

The relative motion in R. A. must be reduced to an arc of a great circle by multiplying it by the cosine of the Moon's declination and since the triangles pCS, MSp, etc., are very small, we can regard them as plane triangles whose sides are expressed in seconds of arc of a great circle.

From the diagram we easily deduce the following equations:

$$\tan i = \frac{d}{\alpha \cos \delta}, \qquad Sp = D \cos i$$
$$Cp = D \sin i, \tag{132}$$

and relative hourly motion in orbit $= \dfrac{d}{\sin i}$

The time of describing Cp, or the interval between the middle of the general eclipse and the time of conjunction, is found by dividing Cp by the relative hourly motion and denoting this interval by t we have

$$t = \frac{D}{d} \sin^2 i \tag{133}$$

the sign of t will be determined by those of D and d. If T_m denote the time of the middle of the eclipse we have

$$T_m = \text{time of } S - t \tag{134}$$

We also have $$\cos v = \frac{Sp}{SM} = \frac{D \cos i}{\Delta} \tag{135}$$

and $$Mp = D \cos i \tan v$$

and if t_1 denote the semi-duration of the eclipse or the time of describing Mp, we have

$$t_1 = \frac{D}{2d} \sin 2i \tan v \tag{136}$$

and therefore, $$\begin{aligned} \text{Beginning} &= T_m - t_1 \\ \text{Ending} &= T_m + t_1 \end{aligned} \tag{137}$$

on the Earth generally.

Let the angle $PSZ = S$ and $PSZ' = S'$, both being estimated from PS toward the east, then we shall have

$$S = (-i) - v \qquad \text{and} \qquad S' = (-i) + v \tag{138}$$

and the spherical triangles PSZ, PSZ' give

$$\cos PZ = \cos PSZ \sin PS, \qquad \tan ZPS = -\frac{\tan PSZ}{\cos PS}$$
$$\cos PZ = \cos PSZ' \sin PS, \qquad \tan Z'PS = -\frac{\tan PSZ'}{\cos PS}$$

$$\text{or} \qquad \sin \varphi' = \cos S \cos \delta', \qquad \tan h = -\frac{\tan S}{\sin \delta'}$$

$$\sin \varphi'_1 = \cos S' \cos \delta', \qquad \tan h' = -\frac{\tan S'}{\sin \delta'} \quad (139)$$

The latitudes thus found are of course geocentric and are reduced to geographical latitudes by (70); the hour angles are measured from PS towards the east and if PG is the meridian of Greenwich, then SPG is the apparent time of beginning or ending and if λ and λ' be the east longitudes of the places and H and H' the Greenwich apparent times we shall evidently have

$$\lambda = h - H \text{ and } \lambda' = h' - H' \quad (140)$$

BEGINNING AND ENDING OF CENTRAL ECLIPSE.

In this case we put $\Delta = H$ according to (131) and then compute v, t_1, S and S' by (135) and (138) and then the geocentric latitude and the longitude by (139) and (140).

To find when and where the *total* eclipse first and last appears at sunrise or sunset, we must use $\Delta = H + s - s'$ for external contact and $\Delta = H - (s - s')$ for internal contact, and for an annular eclipse, $\Delta = H + s' - s$ and $\Delta = H - (s' - s)$ respectively.

TO FIND WHERE THE ECLIPSE IS CENTRAL (TOTAL OR ANNULAR) AT ANY TIME BETWEEN THE DATES OF BEGINNING AND ENDING OF THE CENTRAL ECLIPSE ON THE EARTH GENERALLY.

Let m be the position of the Moon t hours before or after the time T_m or the middle of the eclipse, then

$$mp = \frac{dt}{\sin i}, \qquad \tan v = \frac{2dt}{D \sin 2i} \quad (141)$$

$$\Delta_0 = \frac{D \cos i}{\cos v} = \frac{dt}{\sin i \sin v} \quad (142)$$

$v > 90°$ when Sp is negative

and $$S = (-i) \mp v \quad (143)$$

the upper sign for time before the middle and the lower for time after.

Now in order that an eclipse may be central at any place, the parallax in altitude must be such as will bring the centres of the Moon and Sun into apparent coincidence, and hence by the nature of parallax we have

$$\sin H \sin ZS = \sin \Delta_0$$

or $$\sin z = \frac{\sin \Delta_0}{\sin H} \qquad (144)$$

where z denotes the zenith distance which is of course less than 90°, the Sun being now above the horizon.

In the spherical triangle PZS, we have $ZS = z$ just determined, $PS = 90° - \delta'$ and the angle S, to find the co-latitude PZ and the hour angle ZPS or h. Draw ZQ perpendicular to PS and put $\theta = QS$, then we shall have $\tan \theta = \tan z \cos S$.

$$\tan h = \frac{\sin \theta}{\cos (\theta + \delta')} \tan S \qquad (145)$$

and $$\tan \varphi' = \tan (\theta + \delta') \cos h$$

θ less than 90° and with the same sign as cos S, h in same quadrant as S and δ' the Sun's declination at conjunction.

A check on this formula is easily derived thus

$$\frac{\sin \theta}{\cos (\theta + \delta')} = \frac{\cos S}{\cos h} \cdot \frac{\sin z}{\cos \varphi'}$$

in which all the quantities are involved and which will be satisfied only when all are correct. Finally if H be the Greenwich apparent time we have

$$\lambda = h - H \qquad (146)$$

For a more accurate determination at any time, reduce the difference of parallaxes to the latitude just found, that is correct the value of H and recompute as before.

Central Eclipse at Noon.

During the course of the general central eclipse some place will have the eclipse central at apparent noon. At this time the Sun and Moon will evidently have true as well as apparent conjunction in R. A. and $S = 0$.

The parallax in altitude will bring the centres into apparent coincidence and we shall have

$$\sin z = \frac{\sin D}{\sin H'}$$

and $$\varphi' = \delta' + z \qquad (147)$$

z to have the same sign as D. Apparent time of $\delta = \lambda$ (west longitude of place).

We will now make an application of these formulæ (131) to (147) in the case of the total eclipse of January, 1898, using the elements as given in the *American Ephemeris*, which are as follows:

Greenwich M. T. of δ in R. A. January 21*d* $19^h\ 37^m\ 26^s.5$
$\odot$ and $\mathfrak{D}$'s R.A. $20^h\ 18^m\ 32^s.82$, Hourly motions $10^s.52$ and $147^s.72$
$\odot$'s Declination $-19°\ 38'\ 40''.1$ Hourly motion $+\ 0'\ 34''.5$
$\mathfrak{D}$'s " $-19\ 6\ 27\ .1$ " " $+11\ 34\ .0$
$\odot$'s Equa. Hor. Par. $8\ .9$ $\odot$'s semi-diam. $16\ 15\ .0$
$\mathfrak{D}$'s " " " $1\ 0\ 11\ .6$ $\mathfrak{D}$'s " " $16\ 23\ .3$

From these data we have

$$a = 2058'', \quad d = +659''.5, \quad D = +32'\ 13''$$
$$\pi - \pi' = 60'\ 2''.7, \quad \rho_0(\pi - \pi') = 3596''.62, \quad J = 5554''.9$$

and by (132) we deduce the following results which may be verified by the reader:

$i = 18°\ 44'\ 2''.1$, $Sp = +1830''.59$, $Cp = +620''.82$
$t = +\ 18^m\ 8^s.42$, $T_m = 19^h\ 19^m\ 18^s.1$
$v = 70°\ 45'\ 31''.8$, $t_1 = 2\ 33\ 14\ .7$
Beginning $= 16\ 46\ 3\ .4$
Ending $21\ 52\ 32\ .8$

These results differ from those in the ephemeris by only $0^m.16$ and $0^m.05$ respectively.

By (138) we have $S = -89°\ 29'\ 33''.9$
and $S' = +52\ 1\ 29\ .7$

By (139) we have

$\cos S = 7.9470938$
$\cos\delta' = 9.9739572$
$\sin\varphi = 7.9210510$
$\varphi' = +0°\ 28'\ 39''.8$
$\tan\varphi' = 7.9210661$
$\log(1-e^2)\ \ 9.9970502$
$\tan\varphi\ \ 7.9240159$
$\varphi + 0°\ 28'\ 51''.5$

$\cos S' = 9.7890998$
$\cos\delta' = 9.9739572$
$\sin\varphi' = 9.7630570$
$\varphi' = +35°\ 24'\ 56''.6$
$\tan\varphi_1 = 9.8519160$
$\log(1-e^2)\ \ 9.9970502$
$\tan\varphi_1\ \ 9.8548658$
$\varphi_1 + 35°\ 35'\ 59''$

The ephemeris gives $+0°\ 28'.9$ and $+35°\ 36'.9$

If we now reduce the difference of the horizontal parallaxes to these latitudes and repeat the computation we shall find the agreement practically complete.

For the longitude we have by (139) and (140)

$-\tan S = 2.0528892$
$\sin\delta' = 9.5265748n$
$\tan h = 2.5263144n$
$h = -89°\ 49'\ 46''.08$

$-\tan S'\ \ 0.1075785n$
$\sin\delta'\ \ 9.5265748n$
$\tan h'\ \ 0.5810037$
$h'\ \ 75°\ 17'\ 45''.6$

The Greenwich apparent time of beginning is January 21, $16^h\ 34^m\ 15^s$ and for ending $21^h\ 40^m\ 41^s$, therefore $H = 248°\ 33'\ 45''$ and $H' = 325°\ 10'\ 15''$

then	$\lambda = h - H$	and $\lambda' = h' - H'$
	$= -338^\circ\ 23'\ 31''$	$= -249^\circ\ 52'\ 29''.4$
or	$\lambda = 21^\circ\ 36'\ 29''$ East	or $\lambda' = 110^\circ\ 7'\ 30''.4$ East
ephemeris gives	21 38.7	and 110 4.0
difference	$2^m.2$	$3^m.5$

If, however, we proceed to the second approximation we shall obtain almost identical results.

For the beginning and end of central eclipse we have by (131) $\Delta = \rho_0 (\pi - \pi')$, and by (135) and (136) we have

$$v = 59^\circ\ 24'\ 15''.7 \qquad \text{and } t_1 = 1^h\ 30^m\ 28^s.4$$

and therefore central eclipse begins $17^h\ 48^m\ 49^s.7$
and ends $20\ 49\ 46.5$

By (138) $S = -78^\circ\ 8'\ 17''.8$, and $S' = +40^\circ\ 40'\ 13''.6$
and (139) gives

$\varphi = +11\ 14\ 14$	$h = -85^\circ\ 57'\ 40''$
$\varphi_1 = +45\ 46\ 57$	$h' = +68\ 37\ 54$

The Greenwich apparent times of beginning and end of the central eclipse reduced to arc are respectively

$$H = 264^\circ\ 11'\ 9'' \qquad \text{and } H' = 309^\circ\ 28'\ 50''$$

hence $\lambda = 9^\circ\ 47'.2$ east and $\lambda' = 119^\circ\ 9'.1$ east

To Find Where the Eclipse is Central at Say $20^h\ 20^m$ Greenwich Mean Time.

This date is $1^h\ 0^m\ 42^s$ after the middle of the eclipse, therefore $t = +1.0116 +$ and by (141), (142), (143) and (144) we easily find $v = 48^\circ\ 36'\ 47''.6$, $\log \Delta_0 = 3.44230$ $S = +29^\circ\ 52'\ 45''.5$ and $z = 50^\circ\ 20'\ 28''$ and then by (145) and (146) we have

$\theta = 46^\circ\ 17'\ 9''.3$	$h = 24^\circ\ 55'\ 11''.6$
$H = 302^\circ\ 2'\ 15''$	$\varphi = +24^\circ\ 36'\ 38''.5$

and $\lambda = 82^\circ\ 52'\ 56''$ east, which point is near the western coast of India.

Central Eclipse at Apparent Noon.

By (147) we have, since $D = +32'\ 13''$ and $H = 1^\circ\ 0'\ 2''.1$ (the difference of the horizontal parallaxes reduced to latitude 13° instead of 45°)

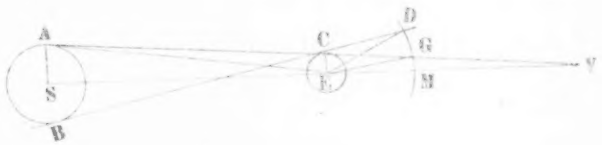
	$z = 32^\circ\ 27'\ 21''$
and	$\varphi' = \delta' + z = +12^\circ\ 48'\ 41''$
reduction to geograph. latitude	$+\quad 5\quad 1$
	$\varphi = +12^\circ\ 53'.7$ See (70).
We also have	$H = \lambda = 291^\circ\ 24'\ 3''$ west

To compute the circumstances of an eclipse for a given place by this method, it would be necessary to compute the parallax in

R. A. and Decl. or the apparent places, then by means of the relative hourly motion in apparent orbit to determine when the apparent distance between the centres, is equal to the sum of the semi-diameters plus the augmentation of the Moon's semi-diameter, all of which involves a considerable amount of labor and is very well explained in detail in Loomis's Practical Astronomy and other similar works to which the reader is referred for further information on this method.

Lunar Eclipses.

The apparent semi-diameter of the Earth's shadow where the Moon crosses it is evidently equal to the sum of the horizontal parallaxes minus the Sun's semi-diameter, for in the diagram we have



Semi-diameter of the umbra $= GEM$

$$\begin{aligned} &= CGE - EVG \\ &= CGE - (AES - EAV) \\ &= \pi - (s' - \pi') \\ &= \pi + \pi' - s' \end{aligned}$$

For the semi diameter of the penumbra we have

$$\begin{aligned} DEM &= GEM + DEG \\ &= GEM + DCG \text{ or } ACB \\ &= \pi + \pi' - s' + 2s' \\ &= \pi + \pi' + s' \end{aligned}$$

If L denote the distance between the centres of the Moon and shadow we shall evidently have for first and last contacts with the penumbra

$$L = (\pi + \pi' + s') + s \qquad (148)$$

For first and last contacts with the umbra

$$L = (\pi + \pi' - s') + s \qquad (149)$$

For first and last internal contacts with the penumbra

$$L = (\pi + \pi' + s') - s \qquad (150)$$

and for the first and last internal contacts with the umbra

$$L = (\pi + \pi' - s') - s \qquad (151)$$

It is necessary to increase the radii of the umbra and penumbra by about $\frac{1}{50}$ or $\frac{1}{60}$ of their values by reason of the effect of the Earth's atmosphere. Let S be the geocentric position of the centre of the Earth's shadow which is directly opposite to that of the Sun; M the geocentric position of the Moon and P the north pole.

Put
α = R. A. of the Moon.
α' = R. A. of S.
= R. A. of the Sun + 180°.
δ = Declination of the Moon.
δ' = " of the Sun.
Q = the angle PSM.
and L = MS.
then $-\delta'$ = Declination of S.
and $\alpha - \alpha'$ = angle MPS.

From the spherical triangle PMS we have

$$\sin L \sin Q = \cos \delta \sin (\alpha - \alpha')$$
$$\sin L \cos Q = \cos \delta' \sin \delta + \sin \delta' \cos \delta \cos (\alpha - \alpha') \quad (152)$$

The eclipse will begin or end when L has the values given by (148)—(151). As the section of the shadow will differ slightly from a circle by reason of the spheroidal figure of the Earth it will be sufficiently accurate to regard the Earth as a sphere with the radius of latitude 45°, which will be equivalent to reducing the equatorial horizontal parallax of the Moon or π to latitude 45, that is, by writing $\rho_0 \pi$ for π where $\log \rho_0 = 9.999266$. Owing to the indefinite outline of both the umbra and penumbra, an accurate computation is unnecessary and therefore we may, instead of, (152) use the following approximate formulæ easily deduced from them:

$$L'' \sin Q = (\alpha - \alpha')'' \cos \delta$$
$$L'' \cos Q = (\delta + \delta')'' - \frac{\sin 2\delta \sin^2 \frac{1}{2} (\alpha - \alpha')}{\sin 1''} \quad (153)$$

The term

$$\frac{\sin 2\delta \sin^2 \frac{1}{2} (\alpha - \alpha')}{\sin 1''}$$

which we will represent by β, can never exceed 30″ and may generally be omitted; its value however can be readily computed or taken from a table of double entry, in which δ and $(\alpha - \alpha')$ are arguments. Such a Table is given in Loomis's *Practical Astronomy*, Table XVIII, page 385, 1st Ed.

If we take S as the origin of a system of rectangular co-ordinates and draw MA perpendicular to PS, we evidently have

$$\begin{aligned} L \sin Q &= x = (\alpha - \alpha') \cos \delta = AM \\ L \cos Q &= y = (\delta + \delta') - \beta = AS \end{aligned} \qquad (154)$$

Now if x and y be computed for several hours preceding and following opposition we shall obtain x' and y' their hourly variations and as in solar eclipses, taking T_0 any assumed epoch near opposition and denoting by x_0 and y_0 the values of x and y for this epoch we shall have for the time of contact $T = T_0 + \tau$, the equations

$$\begin{aligned} L \sin Q &= x_0 + x'\tau \\ L \cos Q &= y_0 + y'\tau \end{aligned} \qquad (155)$$

from which τ can easily be obtained by processes already explained

Put $\quad m \sin M = x_0 \qquad n \sin N = x'$
$\quad m \cos M = y_0 \qquad n \cos N = y'$

then we get

$$\sin \psi = \frac{m \sin (M - N)}{L}$$

$$\tau = \frac{L \cos \psi}{n} - \frac{m \cos (M - N)}{n} \qquad (156)$$

and $\quad T = T_0 + \tau$

where $\cos \psi$ is negative for beginning and positive for the end.

The angle $Q = N + \psi$ is very nearly the supplement to PMS and hence the angle of position of the point of contact, reckoned on the Moon's limb from the north toward the east is $N + \psi + 180°$.

The time of middle of eclipse

$$\text{or } T_m = T_0 - \frac{m}{n} \cos (M - N) \qquad (157)$$

and for the least distance D between the centres we have

$$D = m \sin (M - N) \qquad (158)$$

and if M denote the magnitude of the eclipse we shall evidently have

$$M = \frac{L - D}{2s}, \text{ where } L \text{ is given by (149).}$$

STATIONS FOR OBSERVING THE TOTAL ECLIPSE OF THE SUN IN JANUARY, 1898

The land path of the line of the total eclipse of the Sun commences from a little south of Ratnagiri, on the Bombay coast, and runs in a north-easterly direction to Nepal, passing nearly over Mount Everest, and then disappears in Thibet. The shadow of the Moon will therefore pass through parts of the Bombay Presidency, through Hyderabad, Berars, Central Provinces, and parts of Central India, Bengal, and Northwest Provinces. The length of the path through India is about a thousand miles, and the width of the shadow roughly fifty miles. Hence the area from which observations *could* be taken is enormous. In India, however, facilities for travelling simply do not exist at all over by far the greater part of the country; and as accommodation for European travellers is even more scanty than the means of transport, the number of stations from which observations of the forthcoming eclipse are likely to be made is much smaller than would be expected. As the duration of the total phase of the eclipse on the central line decreases from about two minutes ten seconds on the Bombay coast, to about one minute forty seconds in parts of Bengal and the Northwest Provinces, the natural tendency will be for observers to prefer the western stations. In addition, too, it would appear that the meteorological conditions are more favorable at the western than at the eastern or central stations on the line of totality.

The majority of travellers visiting India for the purpose of observing or seeing the total eclipse will land either at Bombay or Calcutta, probably at the former station. From Bombay several parts of the line of totality can be comfortably visited. The stations on the Bombay coast can be very easily reached by the local steamers of the Bombay Steam Navigation Company. As at present arranged, there is a daily passenger steamer to and from Bombay, calling at such ports as Ratnagiri and Viziadurg, which are close to the central line, and at Jaygad, which is close to the north limit of the line of totality, and at Dewgad, which is just within the southern limit. Combined passenger and cargo steamers also leave Bombay for some of these ports twice or three times weekly. The journey only takes from twelve to eighteen hours each way. The fares are cheap, the first-class fare from Bombay to Ratnagiri being seven rupees; the second, two rupees; and the third, one rupee four annas. It should be remembered that these fares do not include food; also that the

steamers are small, even the combined passenger and cargo steamers having only about five cabins. Hence passengers should take their own bedding and food, and, for comfort's sake, should travel with their own servants.

Several other points on the line of totality can be reached by the railway from Bombay. Commencing with the lines of communication from the west side of India, the train can be taken *via* Kalyan Junction to Poona, passing through the Ghats. From Poona two lines diverge, one to Satara, which is a little north of the central line of totality and well within the northern limit, and from thence to Koregaon, etc., while the second line passes through Sholapur to Hyderabab, etc.; but on this second line there are no considerable stations within the line of totality, nor are there any towns within reasonable distance of the railway, though the smaller stations of Indapur and Kumbhargaon may be easily reached.

Another section of the line of totality can be visited from Bombay by the Great Indian Peninsular Railway *via* Kalyan Junction to Bhusawal Junction, proceeding thence to Amraoti, Pulgaon, Warda and Nagpore. Pulgaon and Nagpore are said to be good stations for the purpose of observation. It should also be stated that Nagpore can be easily reached from Calcutta by the East Indian and Bengal Nagpore lines of railway, the latter railway being joined at Assensole Junction on the East Indian Railway.

Another section of the line of totality can be reached by continuing the journey by the Great Indian Peninsular Railway from Bhusawal Junction to Jubbalpore, where the East Indian Railway is joined, and then passing southwards from Katni by the Bilaspur branch. Again, this railway line crosses the path of the Moon's shadow at a point where there are no towns of any importance.

The other parts of the line of totality which are crossed by the lines of railway could be reached either from Bombay by continuing the journey from Bombay to Allahabad, and then turning southwards on the East Indian main line, or more easily by making Calcutta the starting point, and proceeding northwards from there. The main line of the East Indian Railway crosses the line of totality from a little south of Benares to a little north of Arrah, the considerable station of Buxar being almost on the central line. There is also a small branch line leading to Ghazipur, which is said to be a good place for observations, and is also a fair-sized station. Again, leaving the East Indian Railway at

Bankipore by means of the Bengal and Northwestern Railway, the path of the shadow can be easily visited, the considerable station of Chupra being near the southern limit. Again, by leaving the East Indian Railway at Mokameh, two sections of the shadow path can be reached by the Bengal and Northwestern and Tirhoot Railway, and the most considerable station on these two lines is Motiharee.

There are, therefore, eight sections of the path of the eclipse which are cut by various railways, in addition to the coast line which can be reached by the line of steamers; so that nine sections, or stations on the central line, could be easily occupied if necessary.

A considerable amount of local information as to sites suitable for observing parties has been collected by a committee of the Asiatic Society of Bengal at Calcutta,* and in connection with the inquiries made, the various railway companies on which observing parties would have to travel have very liberally promised to make considerable reductions from their usual rates of fares, and for carriage of luggage, instruments, camp furniture, etc., to all *bona fide* observers and observing parties. Thus the Southern Mahratta Railway, running in the West of India, offer to give free passes to all observers; the Great Indian Peninsular Railway will allow all parties of observers to travel at half rates on ordinary trains; and the East Indian, Bengal and Northwestern and Bengal Nagpore Railways will make a reduction of 25 per cent. from their fares, etc. to observers and observing parties.

It must not, however, be thought that the conditions in India for parties travelling are the same as in England or Europe generally. Food can be had at the various refreshment rooms on all the main lines of railway, but on the branch lines the passenger has frequently to carry his own food. Again, all first and second class passengers travelling at night in Indian railwrys are entitled to a sleeping berth without extra charge; but each passenger must provide his own pillows, rugs, etc , if he wishes to be comfortable.

Again, in the matter of accommodation for visitors, conditions in Indian towns and villages are very different from those in Europe. At such towns as Calcutta, Bombay and Benares hotel accommodation is fairly plentiful; but even here at certain seasons of the year the demand is larger than the supply, and rooms should be engaged beforehand.

* Copies of the information collected could probably be obtained by application to the Honorary Secretary, Bengal Asiatic Society, 57 Park Street Calcutta.

Except at such large towns as those mentioned, or at places on the usual route of tourists, hotels are not to be found, and in the great majority of cases travellers in India have to make their own arrangements for living and accommodation. At the head-quarters stations in the various districts into which India is divided, it is true that Government keeps up small houses called district or travellers' bungalows, or in Bengal called dak bungalows. Travellers' bungalows are to be found at Ratnagiri, also at Indapur and Kumbhargaon in the Sholapur district, Satara (probably) Nagpore, Ghazipur (empty bungalows), Robertsganj (near Mirzapur), Ballia (near Buxar), Chupra, etc. Such bungalows usually contain three or four rooms and are provided with necessary, but not luxurious furniture, and a few servants are in attendance. A small fee is charged for residence; but in the event of a stay of more than twenty-four hours being made, a new arrival has a prior claim to be accommodated over the older residents. The servants at these bungalows can usually provide plain food. Small waiting rooms are to be found at most of the stations on the various lines of railway crossing the path of the eclipse; and the railway companies would probably allow observers to occupy these, but in such cases travellers would have to make their own arrangements for living and sleeping. Failing travellers' bungalows or the waiting rooms at stations, the only plan would be to camp out, and this will probably have to be done in the great majority of cases. Tents and camp furniture can be purchased, and in some cases hired at large towns in India; and in addition the Government of India in the Military Department have promised to lend tents and the ordinary articles of camp furniture *as far as they may be available* for the use of *bona fide* scientific observers who may come out to India for the purpose of witnessing the total eclipse of the Sun. Probably, also, tents could be procured in some instances from the Magistrates and Collectors and other officials of districts who would be certain to give every assistance in their power to observing parties. Here, again, arrangements would have to be made by each party or person as to servants, commissariat, etc. If any station were selected at a distance from large towns or head-quarters of districts, arrangements for food would have to be made beforehand, for only things like fowls, eggs, milk, rice, etc., can be purchased at the smaller stations. Indian servants can, however, always be procured who are accustomed to camp life, and who can take the greater part of the responsibility in making such arrangements.

In a few cases the easily accessible sites near to lines of railway

communication are situated in districts where there are European Indigo and other factories. This is especially the case in Bengal, where the line of totality actually passes through Tirhoot, etc. The managers and other European gentlemen in charge of such factories have a well-deserved reputation for almost boundless hospitality, and an observing party stationed in such a district would be certain of a warm and hearty welcome. The districts, however, in which European planters reside in India are, unfortunately for travellers, comparatively few.—*Nature*, September 2, 1897.

EVENINGS WITH THE STARS.

MARY PROCTOR.

FOR POPULAR ASTRONOMY.

During the month of November, the Great Bear (*Ursa Major*) is on the northern horizon, the Pointers a little east of north, directing the way to the Pole Star. Coiling around between the Great Bear, and the Little Bear, is the Dragon (*Draco*), the tip of the Dragon's Tail lying between the Pointers and the Pole Star. Above are the constellations Cepheus, Cassiopeia and Andromeda, which is nearly overhead. Low down in the northwest Hercules is setting. Above is the Lyre, with the bright Vega, and near by the Swan (*Cygnus*), sometimes called the Northern Cross. Nearly due west we find the Eagle (*Aquila*) with its leading brilliant Altair, and above the Eagle is the pretty little constellation of the Dolphin (*Delphinus*).

Rather low, in the southwest, is the Sea-Goat (*Capricornus*), above and to the south of him the Water Bearer (*Aquarius*) with his pitcher marked by the stars, *Alpha*, *Gamma* and *Zeta*. The head of the Winged Horse, *Pegasus*, is just above this group. The "*Square of Pegasus*" will be noticed high up, due south. The star *Alpha* of Andromeda, one of the corners of this square, was once called *Delta* of Pegasus. Low down in the southern horizon is the Phœnix. The River Eridanus is coming well into view, and the great Sea Monster (*Cetus*) now shows finely, his head marked by *Alpha* and *Gamma*. The Fishes (*Pisces*) are above, the Ram (*Aries*) above them and eastward, lying toward the southeast; then the Triangle, or the Triangles according to modern maps. The giant Orion is rising in the east; above him the Bull (*Taurus*) with the Pleiades. Low down in the northeast the Twins are rising, above is the Charioteer (*Auriga*) and above him the Rescuing Knight Perseus. The Camelopard is hardly worth noticing, except as filling a large space in the heavens, between Cassiopeia and the Great Bear.

The constellations occupy these positions at 9 o'clock, on November 7th; 8½ o'clock on November 14th, and at 8 o'clock on November 22d.

THE CONSTELLATION ANDROMEDA.

If we look directly overhead at 10 o'clock, on the 10th of November, we see Andromeda, a constellation represented in the olden maps by the figure of a woman having her arms extended, and chained by her wrists to a rock.

According to the Grecian legend Andromeda was the daughter of Cepheus and Cassiopeia. The latter imprudently boasted that her daughter was more beauti-

ful than the Nereids. To avenge this insult, a sea-monster was sent to ravage Libya, and destroy Andromeda who was chained to a rock. At the moment the monster was about to devour her, Perseus, who was then returning through the air, from a conquest of the Gorgons, rescued her by turning the monster into stone through the petrifying influence of the Gorgon's head, which he still held in his hand.

TELESCOPIC OBJECTS OF INTEREST.

Alpha Andromedae, or Alpheratz, marks the head of Andromeda, and one corner of the square of Pegasus. It is a double star, the components being white and purple, and of the second and eleventh magnitudes. *Gamma Andromedae*, is a beautiful double star, or rather triple star since the smaller component, is again a very close double, having a companion of the sixth magnitude, 11″ distant. The larger star in *Gamma* is orange, the smaller one green.

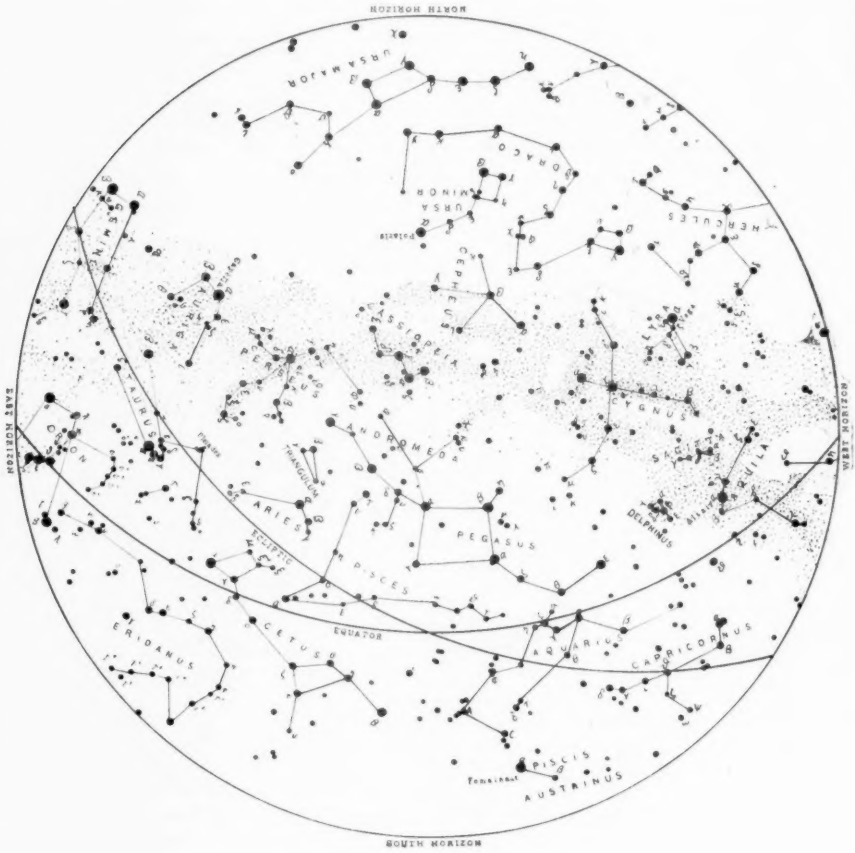
Miss Agnes Clarke refers to *Gamma*, as follows: "Among the most interesting triple stars of the double satellite description is the brilliantly colored Gamma Andromeda. The original components, of third and fifth magnitudes 10″ apart, remain *in statu quo* since they were seen by Father Mayer in 1777, but their secular journey together over an arc of 6° establishes the genuineness of their relationship. In 1842, the sea green companion was found to be itself double. With the fifteen inch Pulkowa refractor, Otto Struve, caught sight of a thin black line (representing probably a gap of some thousands of miles) dividing it into two stars, of respectively 5½ and 7 magnitudes since perceived to be revolving at a rate which would carry them completely round their orbit in about 500 years. They have already progressed so far as to obliterate the "thin black line" testifying to their separate existence. Even Mr. Burnham's keen insight aided by the utmost powers of the Lick thirty-six inch, is no longer adequate to distinguish them. All that can be seen is that the blended object they constitute, instead of being perfectly round, like a truly single star, is slightly oblong in one direction. When the pair was more open than it is now, a difference of tint between the components was noticed by several observers, and it is not improbable that the emerald effect of their light, results from the merging together of actually distinct yellowish-green and blue radiations."*

NEBULA IN ANDROMEDA.

The great Nebula in Andromeda 31 M (Herschel 116) is in a line with Mirach, Mu and Nu (the three stars in the girdle), and about 2° from Nu at the north-western extremity of the girdle. It is the only nebula of the kind which is ever visible to the unaided eye, and has often been mistaken for a comet. Its right ascention is $0^h\ 36^m$, its declination $+ 40°\ 35'$. In fine weather when the moon is absent, this nebula can be clearly seen with an opera-glass. It is mentioned as early as the 10th century, by the Persian astronomer, Suli. In the west, it seems to have been first noticed by Simon Marius, 15th December, 1612. He compared it to a light seen from a great distance through some semi-transparent medium. Later on M. W. Herschel, examined the nebula through his great telescope. The luminous central portion he, too, found to be of a nebulous character but with indications of its being resolvable into separate stars. The middle, or the so-called nucleus of the nebula, has not a starry appearance, but viewed through a powerful telescope it has a certain flashy look which confirms Herschel's opinion of its stellar character. Finally, an examination made in 1848, with the aid of the great refractor at Cambridge, (U. S. A.) proved the existence of upwards of

* *System of the Stars*, p. 206. Agnes M. Clerke

1,500 minute stars within the nebula, while the nebulous character of the whole was still apparent. Two thin, dark parallel streaks, somewhat like two cracks, were found to run through the mass of stars, and have since been noticed by other observers. In the spectroscope, this nebula gives clearly a continuous spectrum, thus proving that it is not a mass of incandescent gas, but rather a highly-condensed star-cluster, at least in the central parts.



THE CONSTELLATIONS AT 9 P. M., NOVEMBER 1, 1897.

About the end of August, 1885, a star of the 6.5 magnitude, suddenly appeared near the centre of the nebula, which gave a continuous spectrum, containing, probably a few bright lines. By the middle of the following September it

had dwindled down to 8.5 magnitude, and in the summer of 1886 had disappeared entirely, even the great refractor at Washington failing to discover it.*

CONSTELLATION OF CASSIOPEIA.

Cassiopeia is represented on celestial maps, seated on a throne or chair, and holding in her left hand the branch of a palm tree. Her head and body are seen in the Milky Way. Her foot rests upon the Arctic Circle, upon which her chair is placed. She is surrounded by Andromeda, her daughter, Cepheus, her husband, and Perseus, her son-in-law.

TELESCOPIC OBJECTS OF INTERERT.

Alpha Cassiopeiæ (Schedar) is a star of the 2.2 magnitude, of ruddy hue, and found to be slightly variable by Birt and John Herschel in 1831. It has a companion of the 9th magnitude, at 60″ distance. R. A. $0^h\ 34^m$, Decl. $+\ 55°\ 53'$.†

Beta Cassiopeiæ (Caph) is a double star, the components being of the 2.5 and 11 magnitudes. Burnham, who observed this star with the 18-inch refractor at Chicago, states that he saw more than a dozen very faint stars nearer to the primary than this companion. R. A. $0^h\ 3^m$, Decl. $+\ 58°\ 29'$.‡

TEMPORARY STAR OF 1572.

R. A. $0^h\ 19^m$, Decl. $+\ 63°\ 24'$. "This is the place of the new star in Cassiopeia, which Tycho observed from the eleventh of November, 1572, till March, 1574, as a star of the first magnltude. D'Arrest has made a list of all the stars in the neighborhood of Nova, with the aid of the large refractor at Copenhagen, and states that any star not yet set down in his chart, which may appear within a radius of 10′ from the place of Nova, may be considered as either new or variable."§

"The star remained visible, we learn, about sixteen months, during which time it kept its place in the heavens without the least variation. 'It had all the radiance of the fixed stars, and twinkled like them; and was in all respects like Sirius, except that it surpassed Sirius in brightness and magnitude.' It appeared larger than Jupiter, which was at that time at its brightest, and was scarcely inferior to Venus. *It did not acquire this lustre gradually*, but shone forth at once of its full size and brightness, 'as if,' said chronicles of the time, 'it had been of instantaneous creation.' In three weeks it shone with full splendor, during which time it could be seen at noonday, by those who had good eyes, and knew where to look for it. But before it had been seen a month, it became visibly smaller, and from the middle of December, 1572, till March, 1574, when it entirely disappeared, it continually diminished in magnitude. 'As it decreased in size it varied in color; at first its light was white and extremely bright; it then became yellowish: afterwards of a ruddy color like Mars; and finished with a pale livid white resembling the color of Saturn."‖

PLANET NOTES FOR NOVEMBER.

H. C. WILSON.

Mercury will be at superior conjunction with the Sun November 7, and will not be visible to the eye during the month.

Venus is the bright morning star seen toward the east by early risers. She is

* Klein's Star Atlas, p. 12. Explanatory text.
† Explanatory Text, p. 12. Klein's Star Atlas. ‡ Ibid, p. 11.
§ Star Atlas. Explanatory Text. p. 11. Klein.
‖ Myths and Marvels of Astronomy. pp. 164-165. R. A. Proctor.

slowly approaching the Sun, passing around to the farther side of her orbit. Her disc is now nine tenths full, but her brightness has diminished to less than a third of that which the planet possessed in June.

Mars, *Saturn* and *Uranus* are also in the vicinity of the Sun. Uranus and Mars will be at conjunction with the Sun and with each other on Nov. 21. Saturn will be at conjunction on the 24th. Mercury will pass Mars on the 12th, Uranus on the 16th, and Saturn on the 18th. Mars and Saturn will be in conjunction on the 27th.

Jupiter is on the meridian at about 9 o'clock in the morning and may be best observed in the morning twilight. The planet is in the western part of the constellation Virgo and will move southeast through that constellation during the month.

Neptune may be observed with the aid of a telescope during the greater part of the night. Its position on Nov. 15 will be Right Ascension $5^h\ 24^m\ 55^s$; Declination north 21° 48′. This is not far from the star δ in the constellation Taurus. Its motion is slow westward.

The *Sun* has been comparatively free from spots during the past month, there being no spots seen on several days.

Occultations Visible at Washington.

Date 1897.		Star's Name.	Magnitude.	IMMERSION. Washington M. T.		Angle from N pt.	EMERSION. Washington M. T.		Angle from N pt.	Duration.	
				h	m	°	h	m	°	h	m
Nov.	1	29 Capricorni	5.7	8	30	73	9	38	221	1	8
	5	45 Piscium	6.9	10	40	3	11	34	284	0	54
	8	μ Arietis	6.0	6	38	128	7	7	179	0	29
	9	66 Arietis†	6 0	4	44	86	5	36	237	0	52
	9	23 Tauri	4.7	15	54	143	16	34	208	0	40
	9	η Tauri	3.1	16	19	103	17	28	250	1	9
	9	27 Tauri	4.0	17	20	121	18	14	235	0	54
	9	28 Tauri	6.2	17	16	100	18	19	256	1	3
	15	o^2 Cancri	6.0	16	22	175	17	12	245	0	50
	17	43 Leonis*	6.5	10	14	133	11	0	267	0	46
	29	50 Capricorni	6.9	5	46	59	7	3	229	1	17
	30	B.A.C. 7951*	6.7	13	23	83	14	10	230	0	47

* Whole occultation below the horizon of Washington.
† Immersion below the horizon of Washington.

The Moon.

		Phases.	Rises. Local Time.	Sets. Local Time.
Nov.	1	First Quarter	1 20 P. M.	11 33 P. M.
	9	Full Moon	4 21 "	8 23 A. M.
	17	Last Quarter	10 53 "	12 48 P. M.
	24	New Moon	7 49 A. M.	4 21 "
	30	First Quarter	12 10 P. M.	11 44 "

VARIABLE STARS.

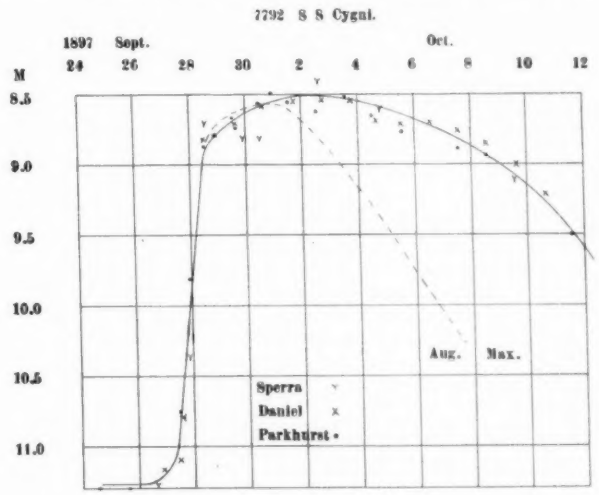
J. A. PARKHURST.

SS CYGNI. The maximum just passed has taught us several interesting facts. In continuation of the reports in the September and October numbers, it should be noticed, first: After a steady decline the star reached its normal light, 11.2 or

11.3 mag., Aug. 20, and remained at that light till Sept. 26. I have 26 observations during this interval. The following observations, in Greenwich time, will show the rise.

	m			m	
Sept. 26.53	11.3	Sperra	Sept. 27.59	10.75	Parkhurst
26.54	11.3	Parkhurst	27.94	9.80	Parkhurst
26.88	11.22	Daniel	27.95	10.4?	Sperra
27.54	11.0	Daniel	28.50	8.82	Daniel
27.56	10.8	Sperra	28 53	8.86	Parkhurst
			28.55	8.7	Sperra.

It is seen from this that the rise from 11.0 mag. to 9.0 mag. occupied nearly 24 hours. It has been suggested that the time of passing some particular magni-



tude in this rapid rise, would furnish a more sharply defined point for reckoning the period, than the actual crest of the curve, which may be uncertain by a whole day. The mean of the magnitudes of the comparison stars *a* and *c* (see Sept. number) would give a good point of reference. Reckoned from this, the interval since the last maximum would be 50 9 days, (Aug. 8.3 to Sept. 28.2) with an uncertainty of not more than 0.1 day. The crest of the curve seems to have been passed about Oct. 2.5, giving an interval of 53.0 days since the last maximum. The star remained above 9th magnitude 10.5 days, as compared with 5.0 days at the August maximum. For convenience of comparison, I have included both light curves in the accompanying illustration, the full line showing the present, the dotted line the August maximum. The resemblance of these two curves to those for U Geminorum, is very striking. See POPULAR ASTRONOMY for May, 1897, page 17.

The accompanying illustration includes 16 observations by Zaccheus Daniel, 11 by W. E. Sperra and 21 by J. A. Parkhurst, but in several cases the agreement is so good that the points are not distinguishable.

Minima of the Variable Stars of the Algol Type

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

1897.

	d	h
Dec.	5	14
	10	14
	15	13
	20	13
	25	13
	30	12

ALGOL.

1897.

	d	h
Dec.	2	15
	5	12
	8	8
	16	23
	19	20
	22	16
	25	13
	28	10
	31	7

λ TAURI.

1897

	d	h
Dec.	13	22
	17	20
	21	19
	25	18
	29	17

S CANCRI.

Dec.	10	14
	29	13

S VELORUM.

1897

	d	h
Dec.	8	14
	14	13
	20	11
	26	10

R CANIS MAJORIS.

1897

	d	h
Dec.	1	18
	2	21
	6	7
	7	11
	8	14
	9	17
	10	18
	11	22
	15	7
	16	11
	17	16
	18	19
	23	8
	24	11
	25	15
	26	18
	27	21
	29	0
	30	4

δ LIBRAE.

1897

	d	h
Dec.	7	18
	21	17
	28	17

U CORONÆ.

Dec.	6	18
	13	15
	30	22

U OPHIUCHI.

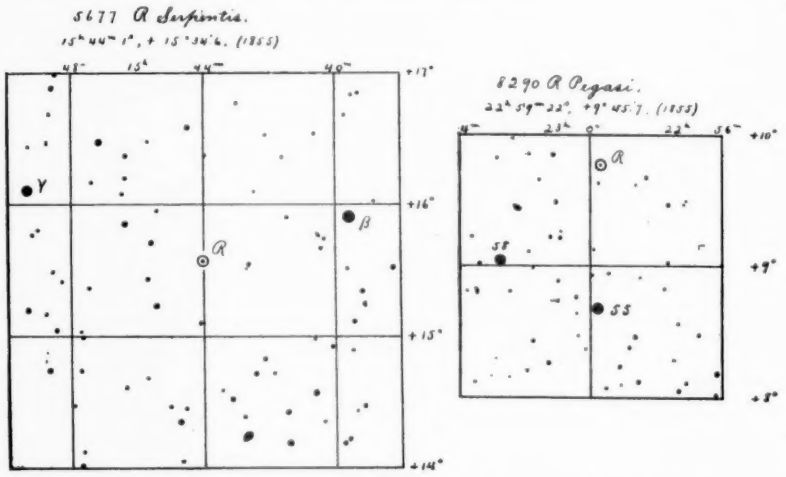
Dec.	8	19
	17	4
	25	14

W DELPHINI.

1897

	d	h
Dec.	2	12
	7	7
	26	13
	31	8

The above ephemeris was computed for POPULAR ASTRONOMY directly from the elements given in Chandler's Third Catalogue and supplements. All the minima are given which occur in the night hours in American and European longitudes when the star is above horizon, except for U Ophiuchi whose period is so short, $20^h\ 7^m\ 43^s$, that only every tenth minimum is given, from which the intermediate ones can be interpolated with sufficient accuracy.



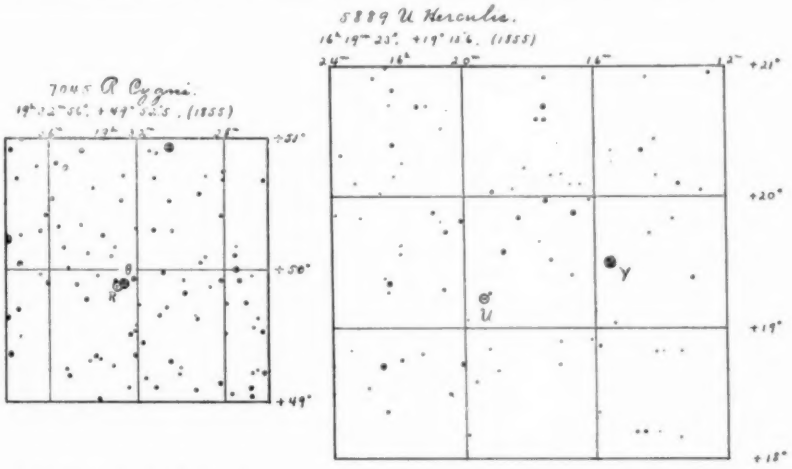
The ephemeris of the long period variables is not given in this number for the following reason. Dr. Chandler has kindly informed me, in a private letter, that he will compute an ephemeris for 1898, which will appear in the *Astronomical*

Journal this fall. Under these circumstances it was thought unnecessary to duplicate his work. It will probably appear in time for the January and February ephemeris to be extracted, and published in the December number.

Variables Suitable for Observation with 2 or 3-inch Telescopes on Portable Stands. Only a limited number of variables become bright enough for observation with these apertures, and a portable stand, especially an alt-azimuth, is not convenient for finding faint stars unless they happen to be near a naked eye star. The following list contains some variables which satisfy the two conditions of brightness and location, being not far from their maxima, and in position for evening observation.

TABLE 1.

Star.	R. A. 1855			Dec.		Redness.	Magnitudes.		Period.
							Max.	min	d
	h	m	s	°	′				
678 U Persei	1	50	0	+ 54	7.0	6 4	7.2 — 8.2	11.6	318
5601 S Ursae min.	15	35	19	+ 79	7.2	7	7.4	11.5	328
5677 R Serpentis	15	44	1	+ 15	34.6	3.7	5.6 — 7.6	13	357
5889 U Herculis	16	19	23	+ 19	13 6	6.5	6.6 — 7.8	11.4 — 12.7	409
7045 R Cygni	19	32	56	+ 49	52 5	6.0	5.9 — 8.0	< 14	426
7609 T Cephei	21	7	33	+ 67	54.4	6.3	5.2 — 6.8	8.6 — 10.7	387
8290 R Pagasi	22	59	22	+ 9	45.7	4	6.9 — 7.9	< 13	380
8324 V Cassiopeae	23	5	27	+ 58	53.8	—	7.1 — 8.0	12.4	229



In Table 2, the first column repeats the number of the variable; the last column gives the number of POPULAR ASTRONOMY in which the chart for the star will be found.

There has lately been a call for such a list of stars for observation with a 2½-inch telescope, on a portable alt-azimuth stand. It is hoped that this list may help some others who have similar instruments, and who would begin observing variables, if the means for finding them were at hand.

TABLE 2

Variable	Finding Star. name	mag.	Variable fron finding star. dist.	direction.	Max. 1897.	P. A. No.
678	g, 4 Persei	4.9	½°	north preceding	Oct.	15
5601	θ Ursae min.	5.3	1⅓°	north	Nov.	37
5677	β Serpentis	3.8	1 °	following	Sept.	47
	γ "	4.0	1¼°	south preceding		
5889	γ Herculis	3.8	1 °	south following	Oct.	47
7045	θ Cygni	4.7	3 ′	following	Dec.	47
7609	β Cephei	3.4	2½°	south preceding	Dec.	6
8290	55 Pegasi	4.7	1 °	north	Sept.	47
	58 "	5.3	1 °	north preceding		
8324	1 Casiopeae	5.0	1 °	following	Sept.	15

The New Variable in Hercules, charted in the October number has received the designation 6100 RV Herculis. It was 12.5 magnitude Sept. 28.

COMET NOTES.

Comet *b* 1897 (Perrine.)—This comet was discovered on the evening of October 16 about 9 o'clock with the new Bruce Comet Seeker of the Lick Observatory.

At $17^h\ 45^m\ 22^s$ Gr. M. T. its position was

$$\alpha\ 3^h\ 36^m\ 7^s.58, \qquad \delta\ +66°\ 46'\ 43''.6$$

It was found to have a daily motion northward of about 1¾° and westward of about 5^m. It will be seen from these circumstances that it is always above the horizon of any place north of 25° north latitude and from its motion it is likely to remain a circumpolar object for some weeks yet.

The comet is only of moderate brightness, but can be seen in a three-inch telescope without difficulty.

There is a well marked condensation which is about equal in brightness to a star of 8th magnitude. This condensation is decidedly elliptical, the longer axes being at least twice the shorter and lying in a great circle passing through the Sun. In this condensation and very near to the end nearest the Sun is a sharply defined star like nucleus of about the 12th magnitude. The diameter of the nebulosity surrounding the head is in the neighborhood of 2′ with a short fan shaped tail extending away from the Sun.

On October 17 it was examined with the 36-inch refractor which showed it much more clearly, and with which a narrow tail could be traced for a distance of 3′ or 4′. The character of the head was much better seen and the nucleus was estimated to be at least as bright as the 12th magnitude.

A photograph was secured on the evening of October 17 with the Crocker photographic telescope by Professor Hussey, upon which the tail can be traced to a distance of 10′.

C. D. PERRINE.

Lick Observatory, University of California,
October 18, 1897.

Elements and Ephemeris of Comet *b*, 1897, Perrine.

From the observations,

G. M. T. 1897	App. α h m s	App. δ ° ′ ″	Observer.
Oct. 16.73515	3 36 6.28	66 46 42.6	Ferrine
" 18.64514	3 24 0.48	69 43 55.9	Hussey
" 20.65788	3 6 21.15	72 46 15.0	Hussey

which are already corrected for parallax and aberration, we have derived the following elements and ephemeris of this comet:

ELEMENTS.

T 1897, Dec. 9.89171 G. M. T.

ω 67 6 55.2
Ω 32 8 37.4 } Mean Equinox 1897.0
i 69 45 43.2

$\log q$ 0.129500

$O - C$: $\Delta\lambda' \cos\beta' = +2''.8$; $\Delta\beta' = +2''.4$

CONSTANTS FOR THE EQUATOR.

$x = r\,[9.937763] \sin(v + 169\ 22\ 43\ 0)$
$y = r\,[9.698274] \sin(v + 169\ 13\ 28\ 3)$
$z = r\,[0.000000] \sin(v + 79\ 20\ 24.7)$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1897, G. M. T.	True α h m s	True δ ° ′ ″	$\log\Delta$	Aber. Time. m s	Brightness
Nov. 1.5	21 22 11.00	80 47 1.6	9.9167	6 51	1.12
" 5.5	19 49 14.74	77 14 27.5	9.9300	7 4	1.09
" 9.5	19 5 20.31	73 0 49.5	9.9462	7 20	1.04
" 13.5	18 42 22.86	68 54 29.5	9.9642	7 38	0.98
" 17.5	18 29 3.59	65 9 10.2	9.9832	7 59	0.92
" 21.5	18 20 45.51	61 48 10.7	0.0025	8 21	0.85
" 25.5	18 15 19.70	58 51 11.4	0.0214	8 43	0.80
" 29.5	18 11 38.97	56 16 27.7	0.0397	9 5	0.74

The brightness at discovery is taken as unity.

W. J. HUSSEY AND R. G. AITKEN.

Lick Observatory, University of California,
Oct. 26, 1897.

Elements of Comet *b* 1897 (Perrine).—The comet has been observed at Goodsell Observatory at every favorable opportunity. With the 16-inch telescope it appears as the miniature of a great comet, somewhat like the comet discovered by Wells of Dudley Observatory in 1882. It has a stellar nucleus of about the 12th magnitude, a narrow bright streak of tail 4′ or 5′ long and a broader and exceedingly faint tail about 10′ long. The bright streak in the tail is so nearly equal in brightness to the very slight condensation around the nucleus, that observers with smaller telescopes will be liable to bisect it rather than the nucleus, and so their observations may be as much as 1′ or 2′ in error. The nucleus is within 5″ of the end of the bright streak, which throughout its length is not more than 15″ wide.

From the observation made by Perrine on Oct. 16, and two observations at Northfield on Oct. 22 and 29, Miss Anne S. Young and the writer have computed the following elements of the comet's orbit:

$$T = 1897 \text{ Dec. } 8.7683 \text{ Gr. M. T.}$$

$$\left.\begin{aligned} \omega &= 66\ \ 1\ \ 32 \\ \Omega &= 32\ \ 3\ \ 38 \\ i &= 69\ \ 36\ \ 17 \end{aligned}\right\} 1897.0$$

$$\log q = 0.132158$$

Representation of middle place, observed − computed: $\Delta\lambda \cos\beta = -2''$; $\Delta\beta = -10''$

From these elements Miss Young has computed the following ephemeris, which represents an observation of Nov. 1 quite closely:

EPHEMERIS OF COMET *b* 1897 (PERRINE.)

Greenwich Midn.	α			δ			log Δ	Brightness.
	h	m	s	°	′	″		
Nov. 10	18	59	13.1	+ 72	5	44	9.9513	1.01
14		39	14.6	68	6	31	9.9698	0.95
18		27	24.7	64	29	34	9.9890	0.88
22		19	56.9	61	16	57	0.0083	0.82
26		15	1.5	58	27	50	0.0271	0.76
30		11	40.4	56	0	20	0.0452	0.71
Dec. 4		9	19.8	53	52	13	0.0623	0.66
8		7	39.3	52	1	21	0.0782	0.61
12	18	6	25.7	+ 50	25	46	0.0929	0.56

CONSTANTS FOR THE EQUATOR.

$$x = r\,[9.938241]\ \sin(168\ \ 20\ \ 19.4 + v)$$
$$y = r\,[9.696837]\ \sin(167\ \ 51\ \ 58.0 + v)$$
$$z = r\,[0.000000]\ \sin(\ 78\ \ 13\ \ 18.3 + v)$$

H. C. WILSON.

GENERAL NOTES.

Much space, this month, is deservedly given to the conferences held in connection with the dedication exercises of the Yerkes Observatory at Williams Bay, Wis. On this account some articles already in type are deferred. The mailing of this number is late in consequence of failures on the part of our engravers.

Resignation of the Director of the Lick Observatory —After a continuous connection with the Lick Observatory for 23 years and a service at Mount Hamilton since 1888, I have terminated my official relations with the observatory to take effect on December 31, 1897. My address after October 1 will be as below:

EDWARD S. HOLDEN,
Smithsonian Institution,
Washington, D. C.

Professor H. S. Pritchett, Superintendent of the U. S. Coast and Geodetic Survey.—From the Washington and St. Louis papers we learn that Professor H. S. Pritchett, of St. Louis has been appointed Superintendent of the United States Coast and Geodetic Survey. Prof. Pritchett is forty-one years old. He studied at Pritchett Institute, Glasgow, Missouri. In 1876 was made computer in the U. S. Naval Observatory under Professor A. Hall, and later was chosen Assistant Professor of Mathematics and Astronomy in Washington University, St. Louis. His connection with the last named University has continued until the present time. He has been a member or director of several astronomical expeditions and he has had large experience in longitude work in the south western part of the Union. The appointment is a most fitting one.

Gifts to the Yerkes Observatory.—President W. R. Harper, in his address at the dedication of the Yerkes Observatory, Thursday, Oct. 22, announced the gifts that had been recently made to the Observatory by Mr. Charles T. Yerkes and others indicating the value of the same as follows:

The great 40-inch lens, $66,000; the mounting of the telescope, $55,000; the dome ninety feet in diameter, $45,000; the Observatory building, $135,000; fifty acres of land for the Observatory site given by Mr. S. Johnson, of Chicago, $50,000; the instruments of the Kenwood Observatory, given by Mr. Hale, value not named, also $3,000 for a spectroscope for the great equatorial.

Dr. Harper also announced that Miss Catherine Bruce of New York City whose munificient aid to the cause of astronomy has already greatly enriched the science, has given to the University of Chicago $7,000 for the purchase of a 10-inch portrait lens or doublet, for the photography of the Milky Way, the comets and the nebulæ, and for the erection of a suitable small Observatory to house the instrument, the same to be placed on the grounds of the Yerkes Observatory, and to be known as the Bruce Astrophotographic Observatory. No provision had been made for an instrument of this kind in connection with the Observatory, though its importance is beyond question. When the matter was presented to Miss Bruce, she generously supplied the money, and the new instrument will soon be made with such particular adaption to photographic work as the large experience of Professor E. E. Barnard will readily suggest. This benefaction is an important one, because by it the work so nobly begun at Lick Observatory by him can now be prosecuted under very favorable circumstances.

The Visiting Astronomers and Physicists in attendance at the conference at the Yerkes Observatory were as follows:

Carl Runge, Director of the Spectroscopic Laboratory Technische Hochschule, Hanover, Germany.

James E Keeler, Director of the Allegheny Observatory, Allegheny, Pa.

Edward C. Pickering, Director of the Harvard Coll. Observatory, Cambridge, Mass.

E. Miller, Professor of Math. and Astronomy, State University, Lawrence, Kansas.

G. W. Myers, Director of the Observatory, University of Illinois, Urbana, Ill.

W. W. Payne, Director Goodsell Observatory of Carleton College, Northfield, Minn.

Frank W. Very, of Ladd Observatory, Providence, R. I.

E. F. Nicols, Hamilton, N. Y.

W. J. Humphreys, University of Virginia, Va.

Kurt Laves, University of Chicago.

Miss S. J. Cunningham, Swarthmore Coll., Pa.

Miss Mary W. Whitney, Observatory, Vassar College, Poughkeepsie, N. Y.

Miss Caroline E. Furness, Observatory Vassar College, Poughkeepsie, N. Y.

Henry Crew, Northwestern University, Evanston, Ill.

Frederick Seares, University of California, Cal.

W. H. Collins, Director of Haverford College Observatory, Haverford, Pa.

Chas. H. Rockwell, Observatory, Tarrytown, N. Y.

Winslow Upton, Director Ladd Observatory of Brown University, Providence, R. I.

Albert Flint, Washburn Observatory, Madison, Wis.

John T. Hedrick, S. J., Georgetown Coll. Observatory, Georgetown, D. C.

Edwin B. Frost, Observatory Dartmouth College, Hanover, N. H.
A. C. Behe, Chicago, Ill.
Goodwin D. Swazey, University of Nebraska, Lincoln, Neb.
Emily Newcomb Wilson, Boston, Mass.
S. L. Pickering, Cambridge, Mass.
Mabel M. Seares, Berkley, Cal.
Simon Newcomb, Washington, D. C.
Henry M. Paul, Naval Observatory, Washington, D. C.
Charles Lane Poor, Johns Hopkins University, Baltimore, Md.
C. L. Doolittle, Director of the Flower Observatory, University of Penn., Philadelphia, Pa.
H. C. Lord, Director of the Emerson McMillan Observatory of the Ohio State University, Columbus, Ohio.
C. M. McCloud, Director of the Observatory of McGill College, Montreal, Ca.
M. B. Snyder, Philadelphia Observatory, Philadelphia, Pa.
J. M. Van Vleck, College, Middletown, Conn.
J. K. Rees, Director of Observatory, Columbia Coll., New York City.
N. E. Bennett, Wilmington, Ohio.
William R. Brooks, Director of Smith Observatory, Geneva, N. Y.
Chas. A. Lundin, Cambridge, Mass.
J. G. Hagen, S. J., Director of Georgetown Coll. Observatory, Georgetown, D. C.
A. G. Stillhamer, Ill. Wesleyan Univ., Bloomington, Ill.
A. W. Quimby, Berwyn, Pa.
E. Colbert, Chicago, Ill.
G. W. Hough, Director Dearborn Observatory, Northwestern University, Evanston, Ill.
William Harkness, Astronomical Director, Naval Observatory, Washington, D. C.
Hugh D. Callendar, McGill University, Montreal, Ca.
J. A. Parkhurst, Marengo, Ill.
G. L. Hall, Colby University, Waterville, Me.
F. R. Moulton, University of Chicago.
A. Hall, Jr., Director of Detroit Observatory, Ann Arbor, Mich.
H. S. Pritchett, Director Observatory, Washington University, St. Louis, Mo.
G. C. Comstock, Director Washburn Observatory, Madison, Wis.
J. A. Brashear, Allegheny, Pa.
Cleveland Abbe, Washington, D. C.
W. R. Warner, of Warner & Swasey, Cleveland, Ohio.

A number of other scientists came near the end of the exercises whose names we were not able to secure. The entire number of visiting members was about seventy.

Correction.—In my note last month about total eclipses of the sun, I wrote as follows: "The Moon cast a shadow on the disk of the Sun!" The types got it thus, "The Moon casts a shadow on the disk of the Sun." Putting that *s* on *cast*, and replacing the exclamation point by a period, changed the meaning entirely, and caused me to make the same error I was complaining of in others. Oh! types. R. W. M.